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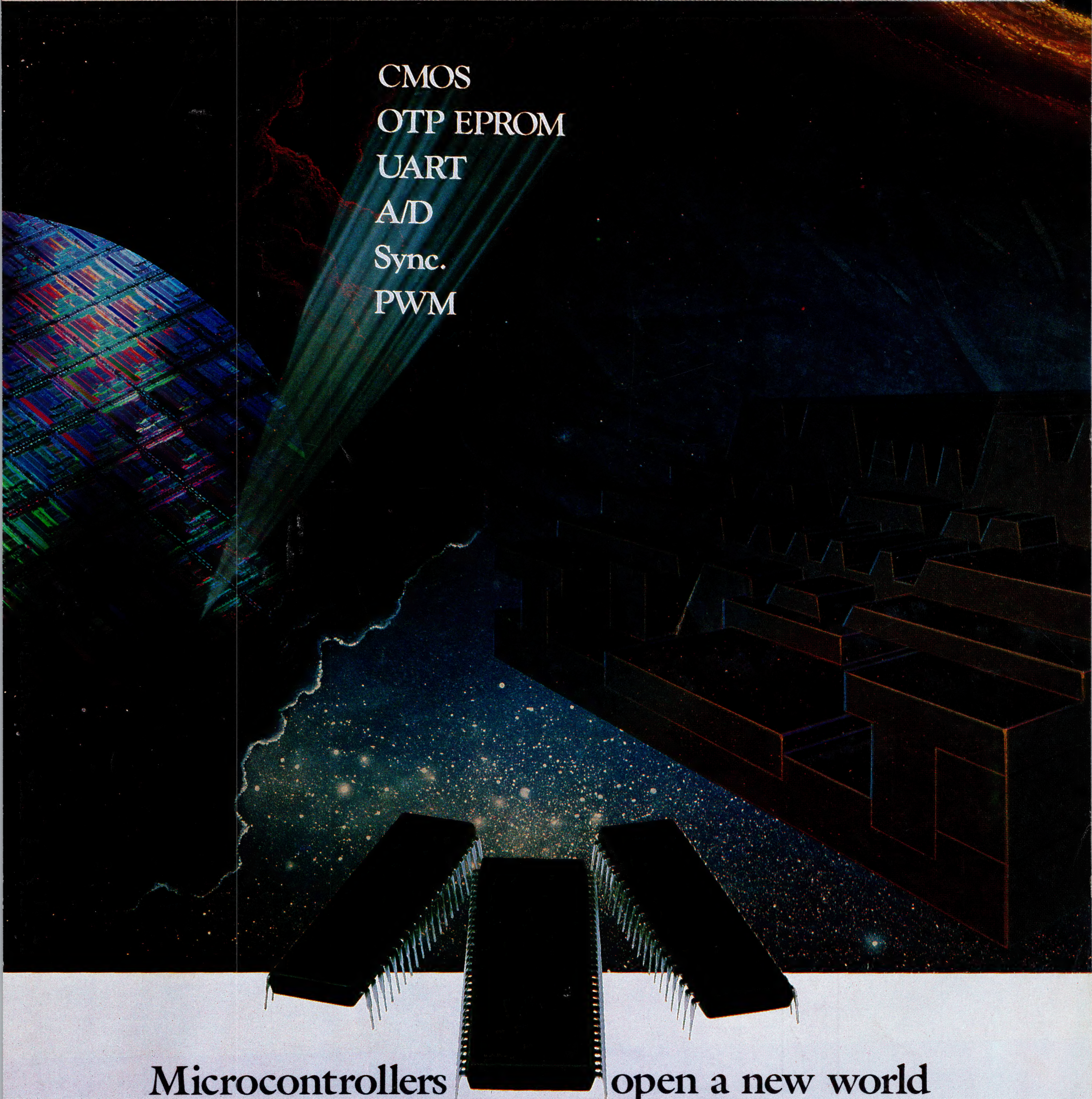
C interpreters and incremental compilers

CMOS flash A/D converters

Technical-article database index

ELECTRONIC TECHNOLOGY FOR ENGINEERS AND ENGINEERING MANAGERS



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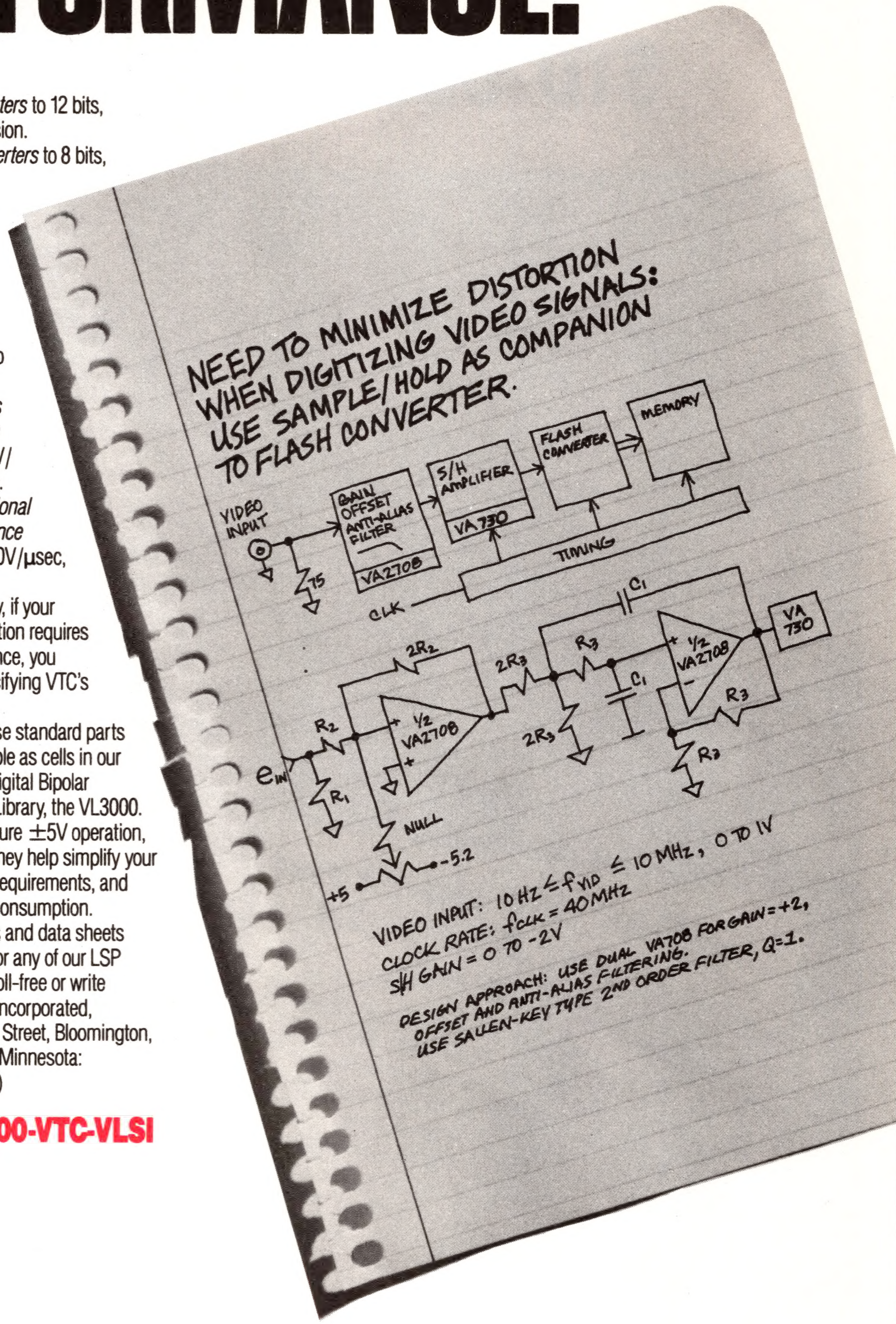

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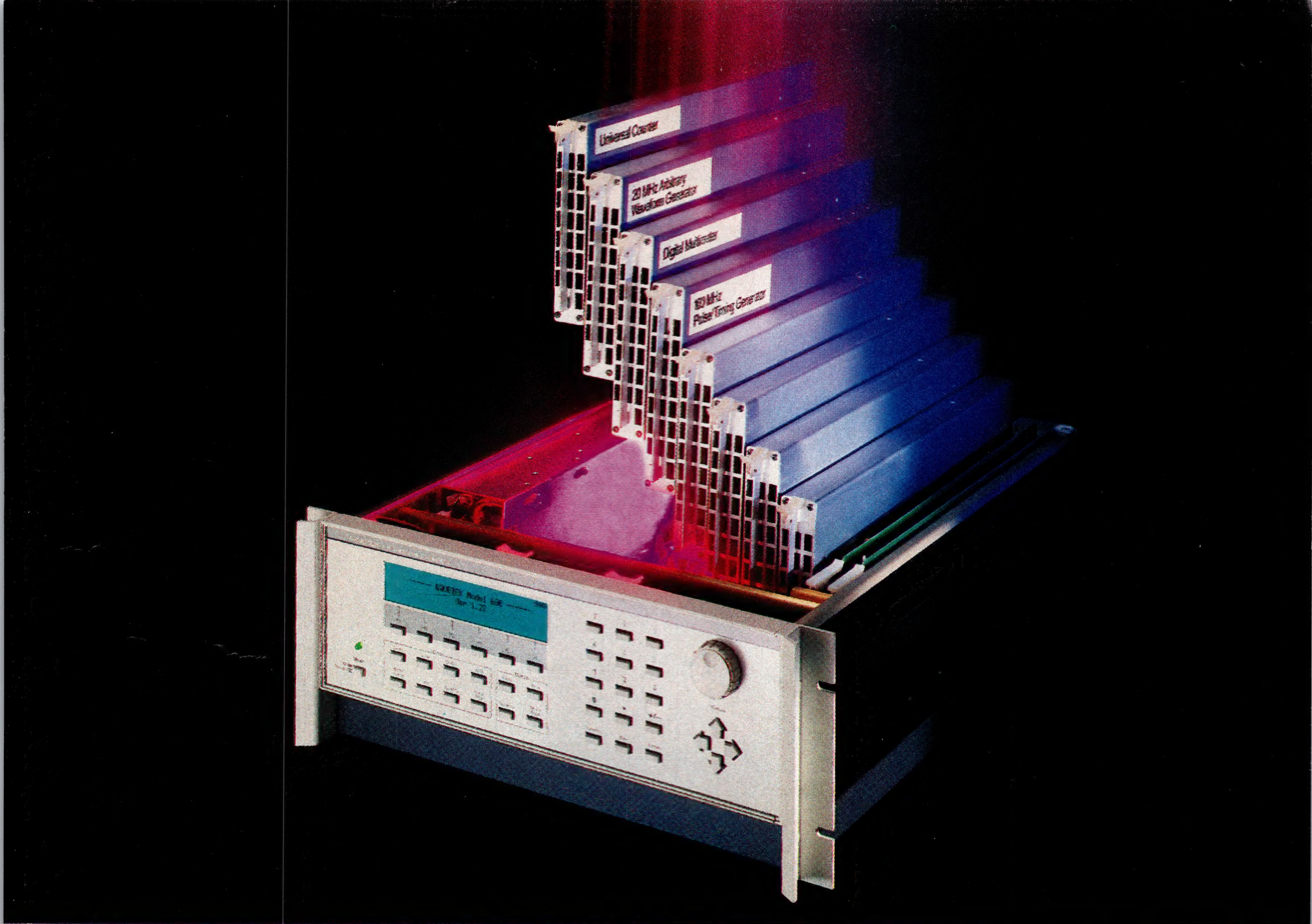

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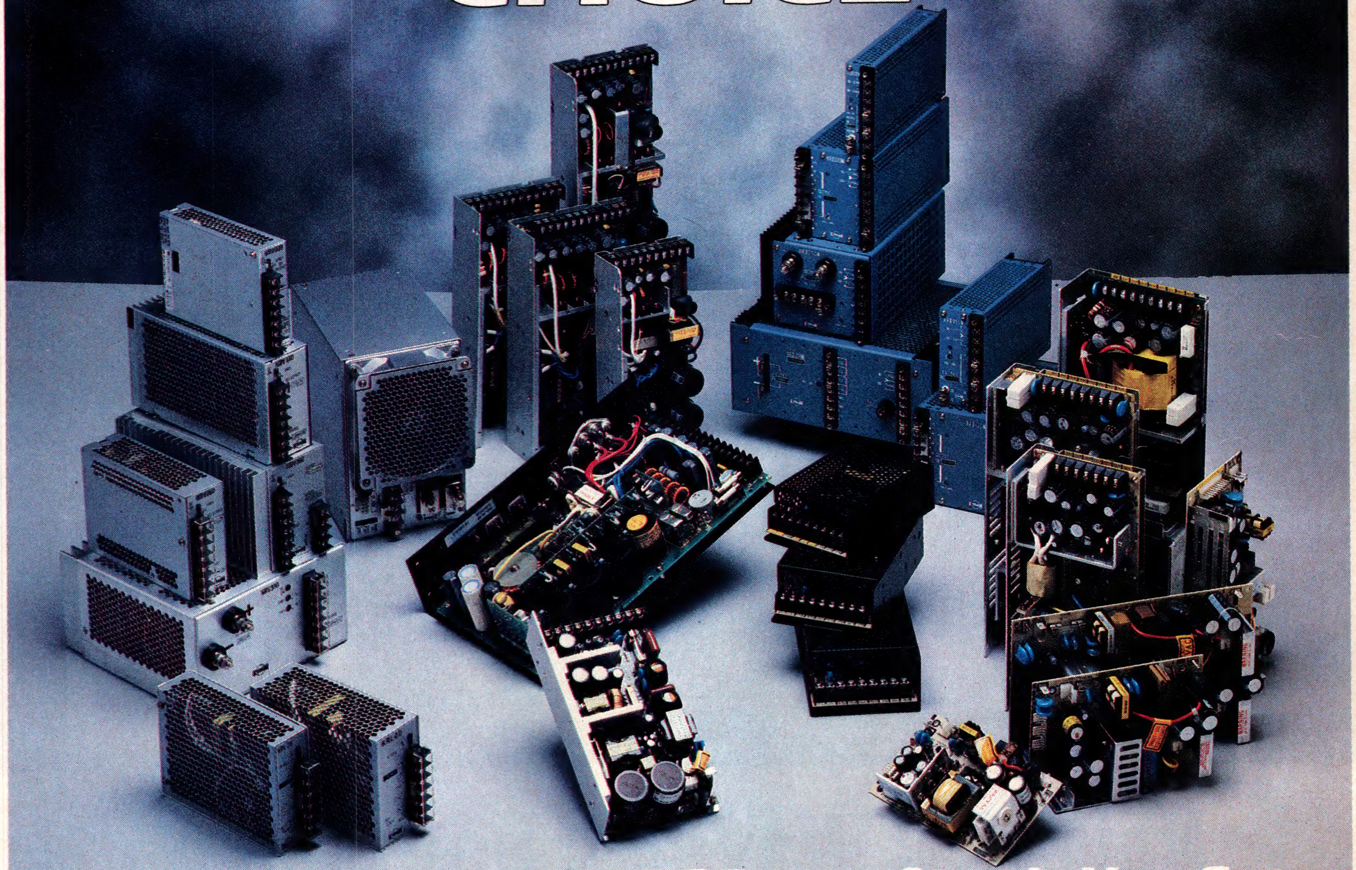

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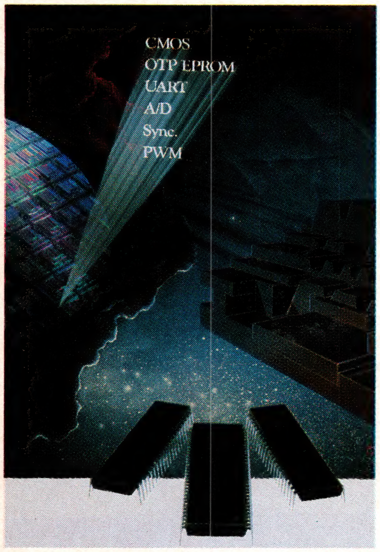
Volume 33, Number 2

EDN

January 21, 1988

ELECTRONIC TECHNOLOGY FOR ENGINEERS AND ENGINEERING MANAGERS



On the cover: *Today's microcontrollers are resplendent with on-chip peripherals—enhancements to the computing core—that satisfy the world of embedded-control applications. See pg 112. (Photo courtesy Hitachi)*

DESIGN FEATURES

Continued on page 7

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BPA ABP

TURN TO PAGE 260

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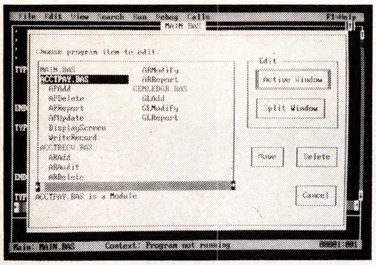

With new integrated development tools, *you can take care of all necessary tasks without going back to the DOS command level (pg 57).*

TECHNOLOGY UPDATE

PRODUCT UPDATE

DESIGN IDEAS

Continued on page 9

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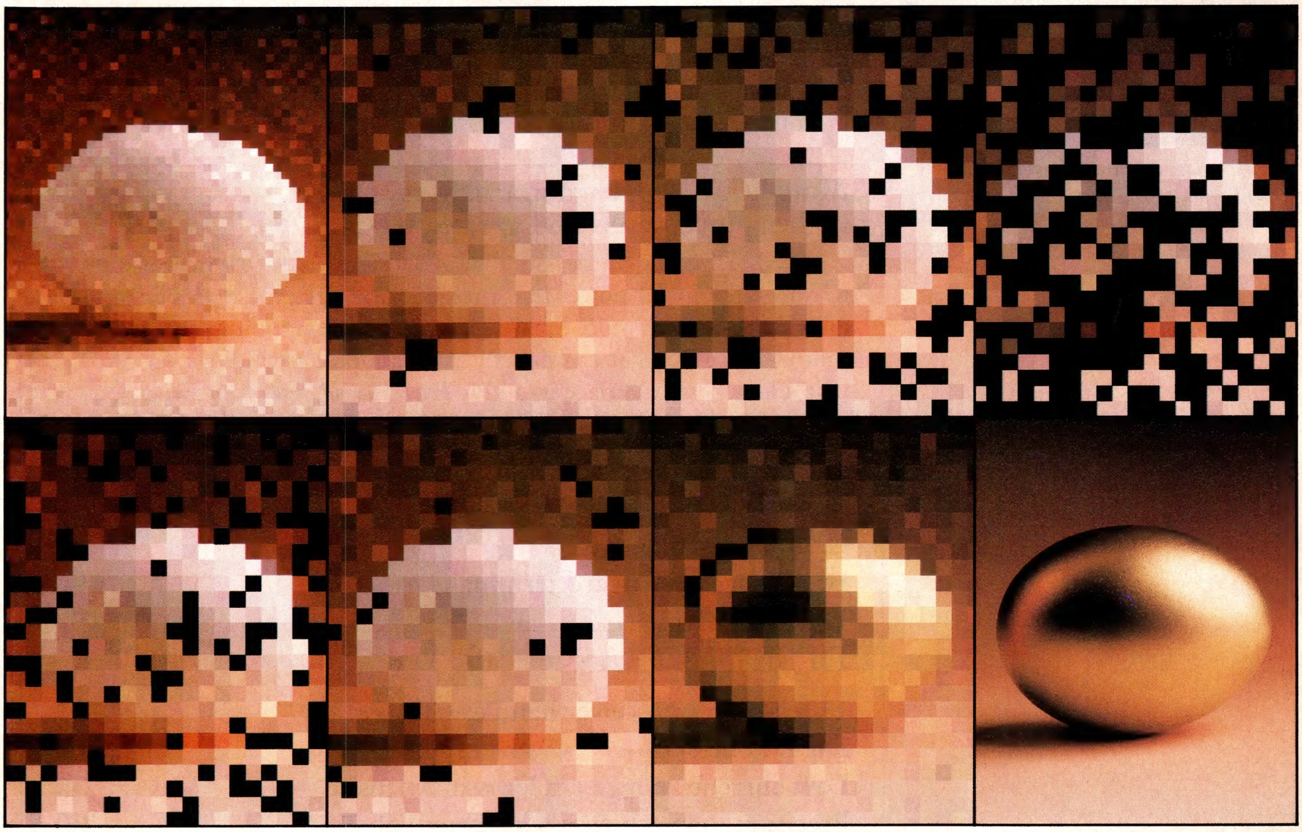

You know how to maintain control and ensure quality of a complex systems project: first you divide it into parts and work on them concurrently, then you put it back together again. You also know how seldom a project survives this kind of reassembly intact—frequently, the final result barely resembles the original intent. Tektronix, a developer of complex systems for many years, now introduces a solution to the problem. This solution is TekCASE: a complete set of software engineering tools and services to guide you through the specification, design, and documentation of even the largest and most complex systems projects. Tektronix supports the entire software development life cycle.

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Continued from page 7

EDITORIAL

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LOOKING AHEAD

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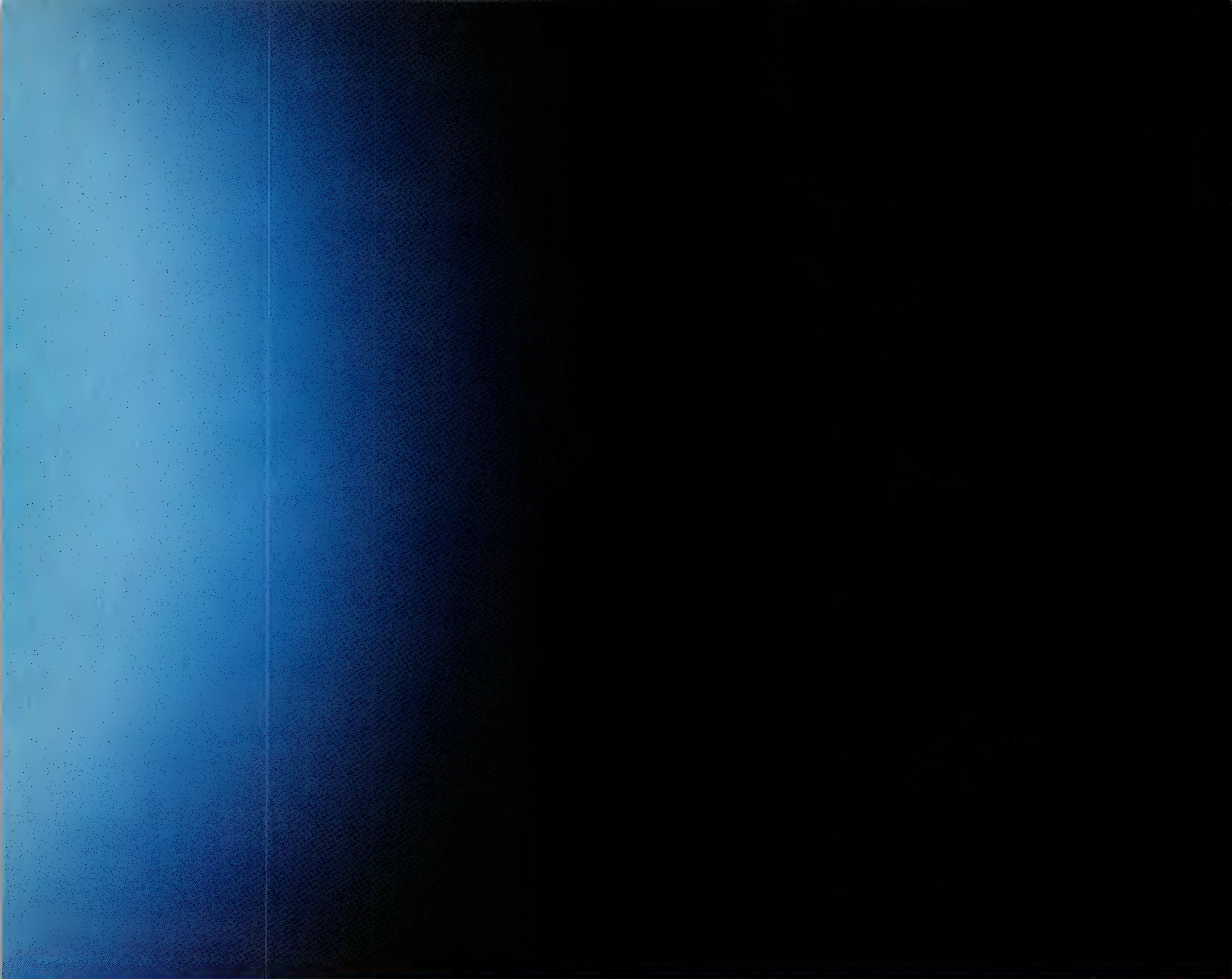

cally to your particular productivity needs. And "case frames" allow very complex circuit patterns to be expressed in just a few keystrokes.

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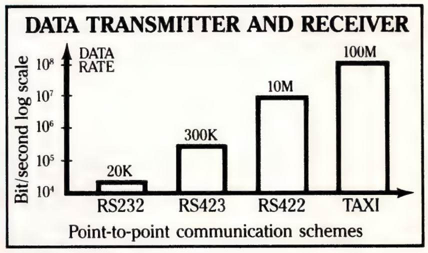

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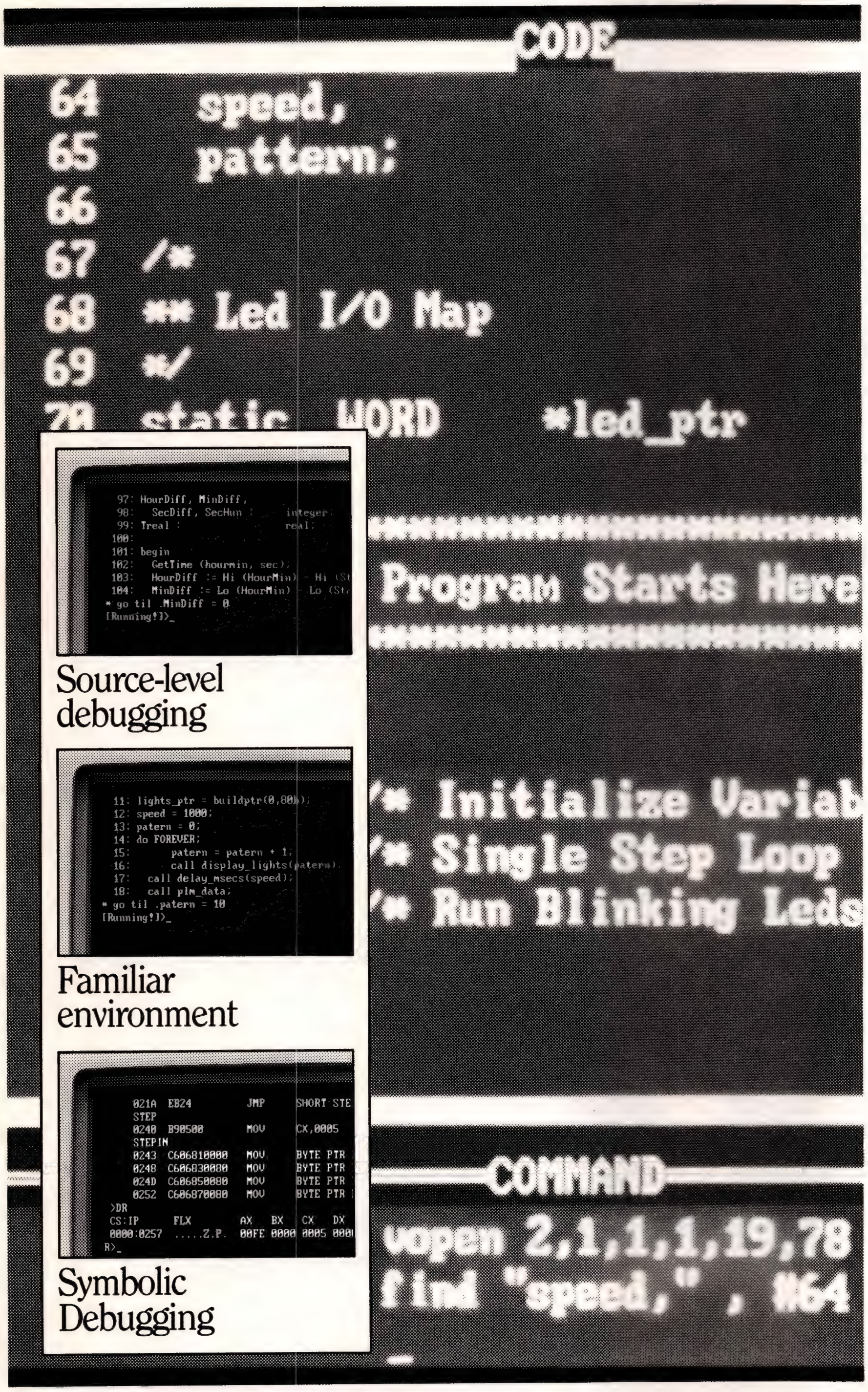

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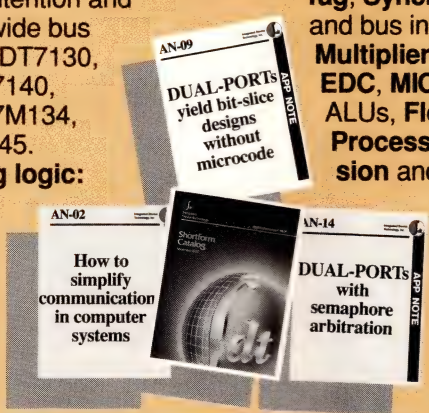

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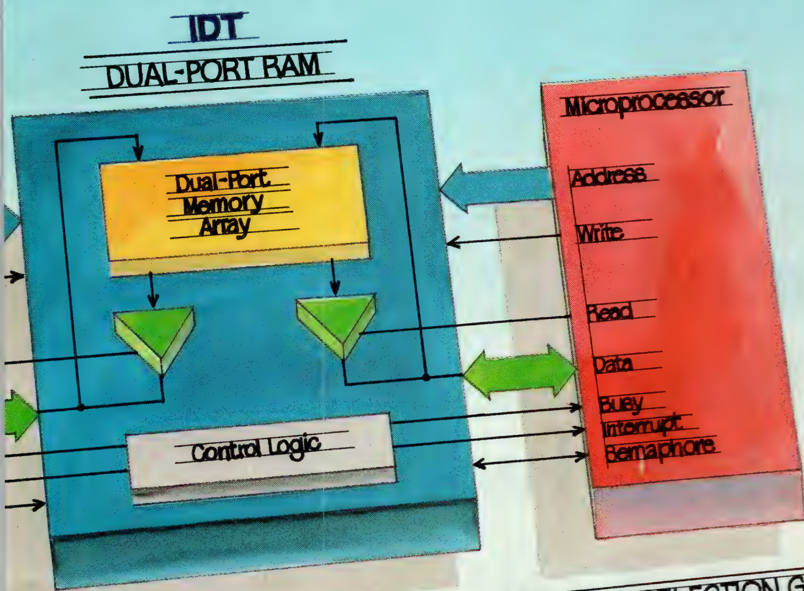
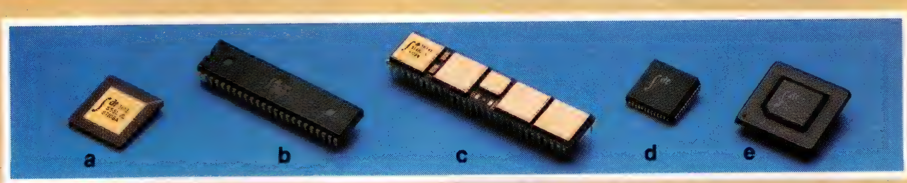


DUAL-PORT SELECTION GUIDE

Description	Part Number	Access Time	Expandability	Control Logic: Interrupt	Control Logic: Busy Logic		Control Logic: Semaphores
1Kx8	IDT 7130	35ns	✓	x	MASTER		
"	IDT 7140	35ns	✓	x		SLAVE	
2Kx8	IDT 7132	35ns	✓		MASTER		
"	IDT 7142	35ns	✓			SLAVE	
"	IDT 71321	35ns	✓	x	MASTER		
"	IDT 71421	35ns	✓	x		SLAVE	
"	IDT 71322	45ns	✓				x
2Kx16	IDT 7133	55ns	✓		MASTER		
"	IDT 7143	55ns	✓			SLAVE	
4Kx8	IDT 7134	45ns	✓				
"	IDT 71342	45ns	✓				x
8Kx8 Module	IDT 7M134	50ns	✓		MASTER		
"	IDT 7M144	50ns	✓			SLAVE	
16Kx8 Module	IDT 7M135	50ns	✓		MASTER		
"	IDT 7M145	50ns	✓			SLAVE	
32Kx8 Module	IDT 7M137	60ns	✓				

(a) Hermetic LCC
(b) Plastic and hermetic DIP
(c) Standard and custom modules
(d) Plastic PLCC
(e) Plastic and hermetic PGA



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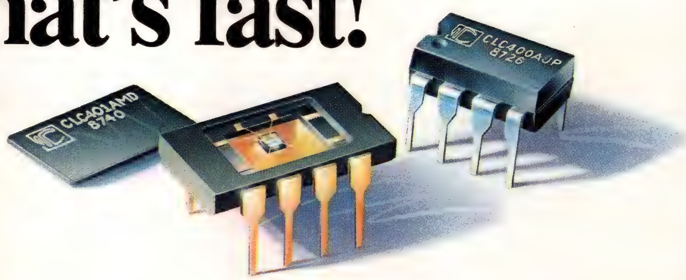

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CIRCLE NO 142

NEWS BREAKS

EDITED BY JOANNE CLAY

MOTOROLA ISSUES MICROCONTROLLER PHASE-OUT WARNING

Motorola Inc (Phoenix, AZ, (512) 440-2035) is warning designers: Avoid using certain Hitachi microcontrollers in new designs. Because a cross-licensing and comprehensive patent agreement between Hitachi (Tokyo, Japan) and Motorola is no longer in effect, Hitachi will phase out six microcontroller products during the next two to three years. The microcontrollers include five one-time-programmable (OTP) devices: the V, X, and Y versions of the HD63701, as well as the V and Z versions of the HD63705. Hitachi will also phase out the HD6305Z, a ROM-based microcontroller chip. Motorola expects Hitachi to phase out the HD63701 OTP devices by March 31, 1991, but the six other controller chips will meet an earlier demise—March 31, 1990.

To support the Hitachi microcontroller architectures, Motorola is developing OTP versions of its M68HC11, MC68HC05, and MC68HC04 product families. The manufacturer also recommends the ROM-based versions of the same product families. Evaluation modules and a development system are available now.—Jon Titus

SMD VARISTOR PROTECTS CIRCUITRY FROM VOLTAGE TRANSIENTS

Available in either a minuscule 1206 SMD package or a more conventional axial-leaded package, the MLV multilayer varistor from AVX Corp (Myrtle Beach, SC, (803) 448-9411) provides bipolar protection from transient voltages caused by ESD, lightning, inductive switching, and nuclear electromagnetic pulses. The company offers the device with either 15.5 or 30V clamping voltages for logic and automotive applications, respectively. Although these clamping voltages may seem high at first glance, they're not: Most of today's semiconductors feature ESD-protection ratings of 500 to 2000V, so the MLV clips transient voltages well below damaging levels. The manufacturer rates the devices for peak currents of 200A. The SMD and axial devices cost $0.49 and $0.54 (10,000), respectively.—Steven H Leibson

SYNCHRO-TO-DIGITAL CONVERTER IS ACCURATE TO 6 ARC SEC

Because it's accurate to 6 arc sec, the SD(RD)570 synchro-to-digital converter is suitable for use in high-accuracy synchro-conversion and control systems. You can also use the converter as a secondary standard for evaluating synchro-conversion products. The manufacturer, Natel Engineering Inc (Simi Valley, CA, (805) 581-3950), claims that the SD(RD)570 is the most accurate synchro-to-digital converter ever offered as a standard product. The 20-bit converter features a resolution of 1.24 arc sec and a tracking rate of 720°/sec. Packaged in a single encapsulated module, the 570 is available in both commercial and military versions. From $2400.—Margery S Conner

RUGGED BUBBLE-MEMORY SUBSYSTEM FOR STD BUS

Designed for harsh industrial environments, the ZT8854 bubble-memory subsystem from Ziatech (San Luis Obispo, CA, (805) 541-0488) provides 720k bytes of storage on cartridges that have an estimated MTBF (mean time between failures) rate of 40 years. The bubble-memory subsystem is a functional replacement for 3.5-in. disk drives, and you can plug the subsystem directly into an STD Bus card cage. The unit combines a Magnesys Corp (Santa Clara, CA) electronic drive and removable cartridge with Ziatech's disk-drive controller and STD DOS driver software. Ziatech's disk-drive controller can also control hard-disk and floppy-disk drives, and it includes a SCSI-compatible host adapter. It costs $1800 and comes with a removable cartridge.

—Doug Conner

NEWS BREAKS

SINGLE-CHIP VGA HAS BUILT-IN VIDEO-RAM CONTROL

The V7VGA VGA-compatible chip from Video 7 (Fremont, CA, (415) 656-7800) is the first graphics-controller IC for IBM PC- and PS/2-compatible computers that supports video RAM. Video RAMs' faster response times will be beneficial in 80386-based workstations. Because the faster memory architecture is software independent, the board will speed the operation of any VGA-compatible software package. The chip also features a 1-byte buffer that can hold one instruction from the CPU; when the system is running CPU-intensive software, the VGA appears to have no virtual wait states.

In addition to controlling video RAMs, the board emulates all IBM VGA registers (at best, most other VGA-compatible chip sets give programmers access to the CRT control registers). IBM has not documented all of the registers on the VGA; some manufacturers of graphics chip sets have assumed that the undocumented registers are used only for diagnostics. Video 7, however, claims that two of the registers are status registers that allow a programmer to manipulate the graphics hardware even in a multiprogramming environment. Additionally, the company claims that some system-level software packages, such as OS/2 and Windows 386, manipulate these registers directly, and that current VGA-clone boards have trouble running the new system-level software because they lack these registers. The chip is available now in sample quantities. It will be available for about $50 in OEM quantities by the end of 1988.

—Margery S Conner

12-BIT A/D CONVERTER SPECS 7-μSEC CONVERSIONS

You can now order a self-calibrating, 12-bit sampling A/D converter that performs 7-μsec conversions with 100-kHz throughput. The CS5012-7 from Crystal Semiconductor (Austin, TX, (512) 445-7222) provides full 12-bit accuracy to within a maximum of ±½ least significant bits (LSBs) over temperature and time. An on-chip sample-and-hold amplifier lets the chip work without external components for ac-signal conversion. The chip includes a microcontroller that maintains ±¼-LSB nonlinearity and error limitation. Its aperture jitter clocks in at 100 psec, and it consumes 120 mW of power. The CS5012-7 costs $43.70 (100).—J D Mosley

LOW-COST TEXT-TO-SPEECH BOARD PLUGS INTO PCs

The Accent-mini board for IBM PCs and compatible computers converts ASCII files into intelligible speech. It costs $245. The board has a standard vocabulary of about 15,000 words; you can add as many as 2000 more words by ordering the custom vocabulary option. Accent-mini can speak in two modes: text mode and spell mode. In text mode, the board converts ASCII text into ordinary speech, employing grammatical rules to determine special cases such as words having two pronunciations, and symbols and signs such as %, $, and @. The board can use punctuation marks for intonations, so you can choose between monotonic and nonmonotonic (intonated) speech. (Monotonic speech is useful in reading machines for the blind because people can assimilate monotonic speech spoken at high speed much more readily than they can assimilate high-speed intonated speech.) In spell mode, the board speaks all text, including punctuation, letter by letter. You can program such parameters as speech rate, tone and monotone pitch, and voice characteristic. From Aicom Corp (San Jose, CA, (408) 922-0855).—Margery S Conner

NEWS BREAKS: INTERNATIONAL

I/O CARDS LINK VME BUS SYSTEMS TO TOKEN-RING NETWORKS

Representing the first product in a family of intelligent I/O subsystems, the CC-96/103 board set from Compcontrol (Eindhoven, The Netherlands, TLX 51603) interfaces VME Bus systems to IBM token-ring networks. The mother board, which will be common to all members of the family, includes a 68020 μP, a 68881 math coprocessor, 1M byte of zero-wait-state dynamic RAM, and 128k bytes of dual-port static RAM. The board's VME Bus interface can transfer data to and from the host system at data rates as high as 33M bytes/sec. A second board, mounted alongside the mother board and behind a single front panel, interfaces to the token-ring network by means of a Texas Instruments token-ring chip set. Support software for the board is under development. Initial samples of the subsystem are expected to sell for around $15,000.—Peter Harold

LOW-COST PHOTOPLOTTER SUITS IBM PC-BASED PC-BOARD CAD SYSTEMS

Priced at less than £15,000 and suitable for tabletop operation, the P15 flatbed photoplotter from Electronic Industrial Equipment SA (Geneva, Switzerland, TLX 429484) offers CAD users an alternative to outside photoplotting services. The photoplotter has an 11.8×15.75-in. (300×400-mm) plotting area, on which it achieves a positional accuracy of ±0.001 in. (0.025 mm). The plotter's print head provides 32 fixed symbols, each driven by a separate LED. The photoplotter interfaces to a host computer via an RS-232C interface, and it accepts RS-274 (Gerber) plot information. Control software running under MS-DOS is optional.—Peter Harold

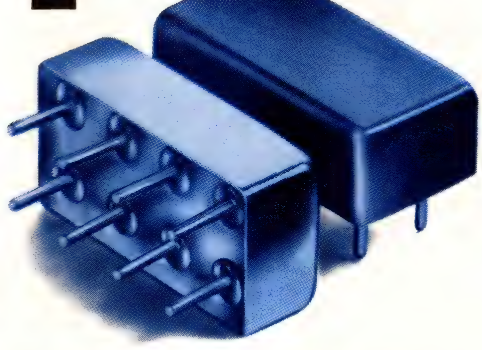
SINGLE CHIP INCORPORATES IMAGE-PROCESSING CIRCUITS

Hitachi Ltd's ISP-II is a 1-chip VLSI image-processing circuit. The device reputedly has four times the image-processing capability of existing image-processing systems. The chip is fabricated in a 1.8-μm bipolar-CMOS process, and its clock speed is 25 MHz. The chip can process TV images in real time at 6 MHz. It allows you to program virtually all front-end image-processing tasks, such as pattern matching of binary images and distance computation of colored images. The company plans to introduce several systems containing the device early in 1988.—Joanne Clay

PC-BASED COMMUNICATIONS PACKAGE PROVIDES LOW-COST FAX

With the PC-Fax package from Softech Professional Systems Ltd (Tonbridge, UK, FAX (0732) 770263) you can use your IBM PC/XT, PC/AT, or compatible computer to send facsimile (fax) messages to and receive them from any International Group-III fax machine. The £750 package, which includes all the necessary interface hardware for the phone line, allows you to send fax, telex, or electronic-mail messages. The fax software can grab screen images, so you can transmit any image from a word processor, desktop publisher, or paintbrush system. You can also enter information from the PC's memory or keyboard, from an optional digitizer tablet, or by scanning hard copy with a suitable scanner or existing fax machine. The package can also capture and transmit drawings generated by CAD packages, and it doesn't limit document size.—Peter Harold

rugged plug-in amplifiers



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MAN-1	0.5-500	28	1.0	8	4.5	60	13.95
MAN-2	0.5-1000	19	1.5	7	6.0	85	15.95
MAN-1LN	0.5-500	28	1.0	8	2.8	60	15.95
◇MAN-1HLN	10-500	10	0.8	15	3.7	70	15.95

††Midband $10f_L$ to $f_{u/2}$, ± 0.5dB †1dB Gain Compression ◇Case Height 0.3 In.
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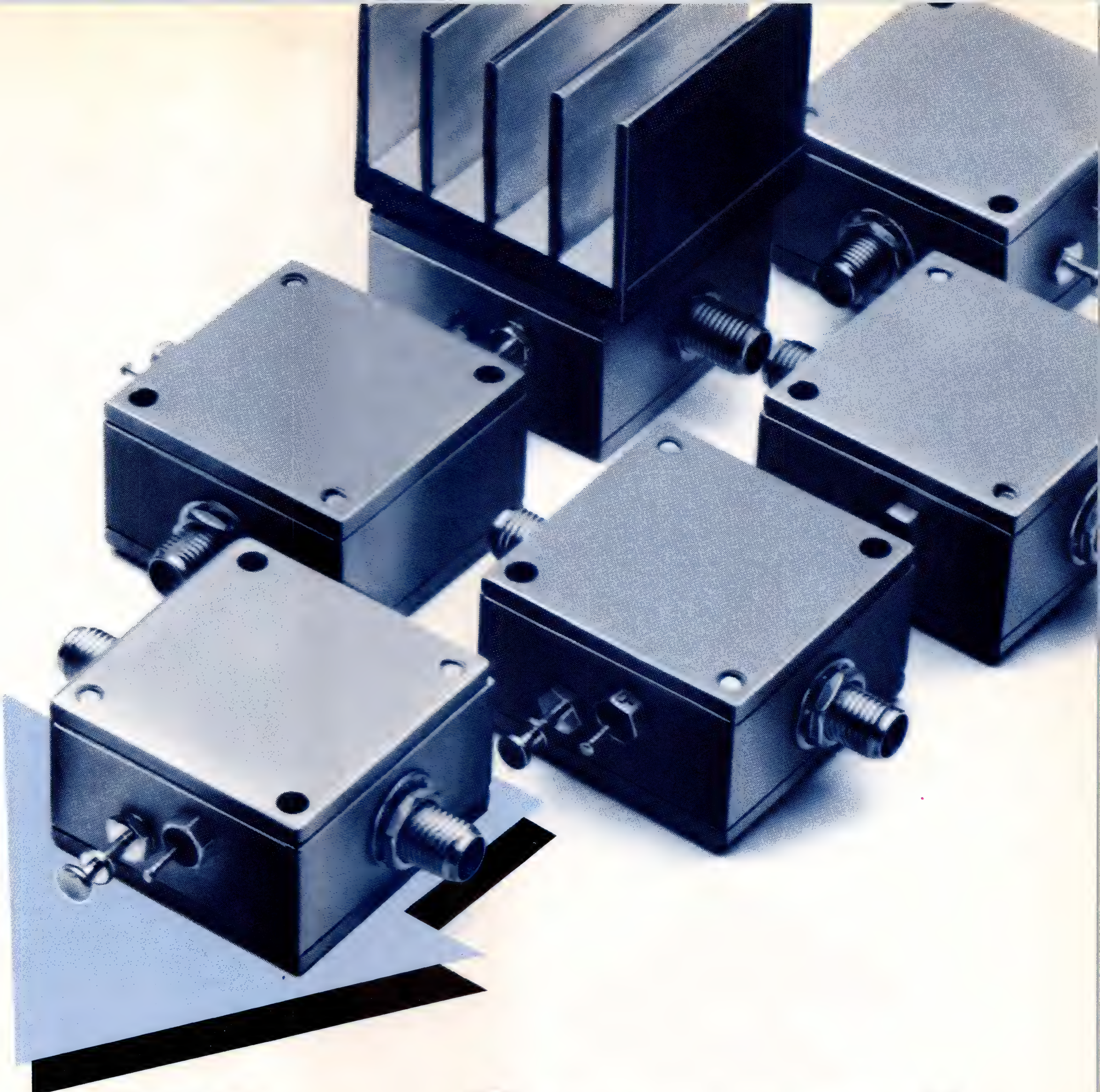
CIRCLE NO 163

C118 REV. B

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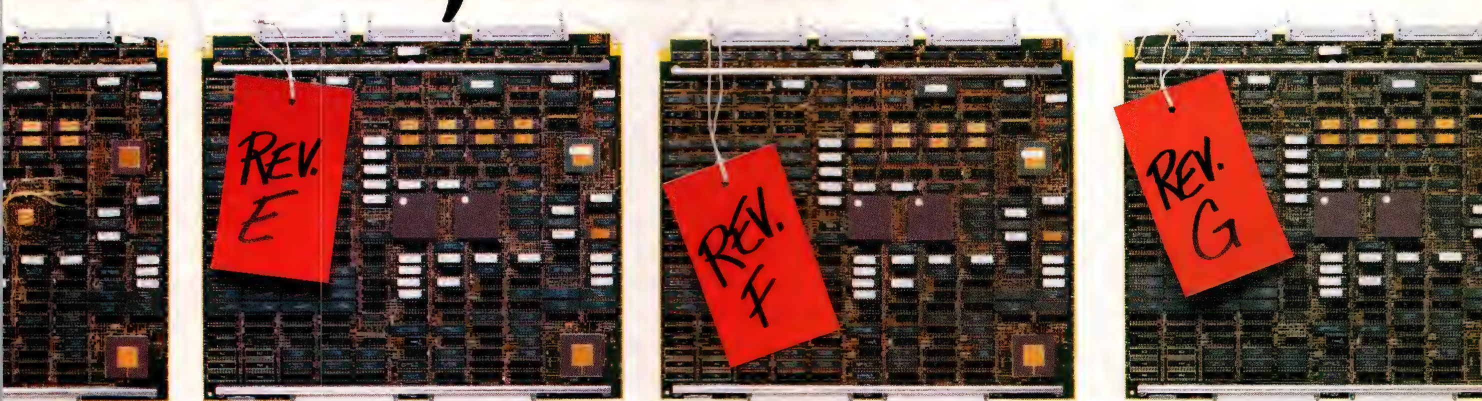

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CIRCLE NO 146

SIGNALS & NOISE

Cluster testing isn't the answer

This letter is a vociferous protest against the article "Cluster testing overcomes many testability problems" (EDN, October 15, 1987, pg 133).

Articles like these, written by ATE vendors trying to perpetuate sales of high-priced test equipment, do your readers a disservice. Yes, you can spend $1.5 million to overcome your testability problems. Many US companies continue to do so, which is one reason that the country still is not as competitive in electronics manufacturing as it could be.

The objective is not to *overcome* testability problems; it's to *prevent* them. Computers continue to become smaller, more powerful, and less expensive. Testers continue to become larger, incrementally less powerful, and much more expensive. Why? Because the units under test (UUTs) are not testable. Ample evidence exists to show that one day invested during design to eliminate testability problems saves weeks and even months during test preparation. That equals shorter time to market. Evidence also exists to prove that testable designs can be tested on much less expensive test equipment.

Some ATE companies' CEOs have admitted in print that they pay lip service to testability because its widespread implementation would lower the average selling price of testers and thus hurt the ATE vendors' profit margins. It's my opinion that if an approximately $1 billion industry has to hurt a little in order to let the entire US electronics manufacturing industry become more competitive, it should take that hurt.

There will always be a market for expensive ATE, particularly in the design-verification, product-characterization, and qualification phases, even when the UUTs are designed to be testable. So the ATE vendors have no reason to fear real functional testability. They might even find that making their tester designs testable can save them enough money to improve margins and enjoy a healthy business while helping their customers and thereby preserving their future markets.

Cluster testing is a euphemism for testing a group of components when you can't test the individual components because the UUT lacks the inherent testability attributes of partitioning, control, and visibility. It's another patch on the problem. Let's get smart and start testing testable clusters, commonly called circuit boards, which are normally tested from the edge connector of the circuit board plus whatever testability access has been provided.

Running articles about "overcoming" testability problems perpetuates the design engineer's belief that designing untestable circuits is okay because the test people can "overcome" the problems. But at what cost and in how much time can the test people overcome them? Designers must make sure that their most elegant designs are also manu-

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facturable, testable, on time, and profitable.

The electronics manufacturing industry needs cooperation between design and test functions, not new testers. Early test involvement that continues throughout the design phase will prevent testability problems. And prevention is much cheaper, and smarter, than "overcoming" after the fact.

Jon Turino
Logical Solutions Technology Inc
Campbell, CA

Erratum

The article "Coherent sampling helps when specifying DSP A/D converters" (EDN, October 15, 1987, pg 145) contained an error in the equation on page 146.

The correct equation is

$$WH(n) = \begin{bmatrix} 0.5+0.5\cos\left(\frac{2\pi n}{N}\right), & \frac{-(N-1)}{2} < n < \frac{(N-1)}{2} \\ 0, & \text{elsewhere} \end{bmatrix}$$

Thanks to J M Santiago of the US Naval Research Laboratory (Washington, DC) for catching this error.

Breaking the law

In the Design Idea "Op-amp current mirror drives load current" (EDN, November 12, 1987, page 289), the output pulse width (T) isn't a linear function of the digital input (D), but follows the law

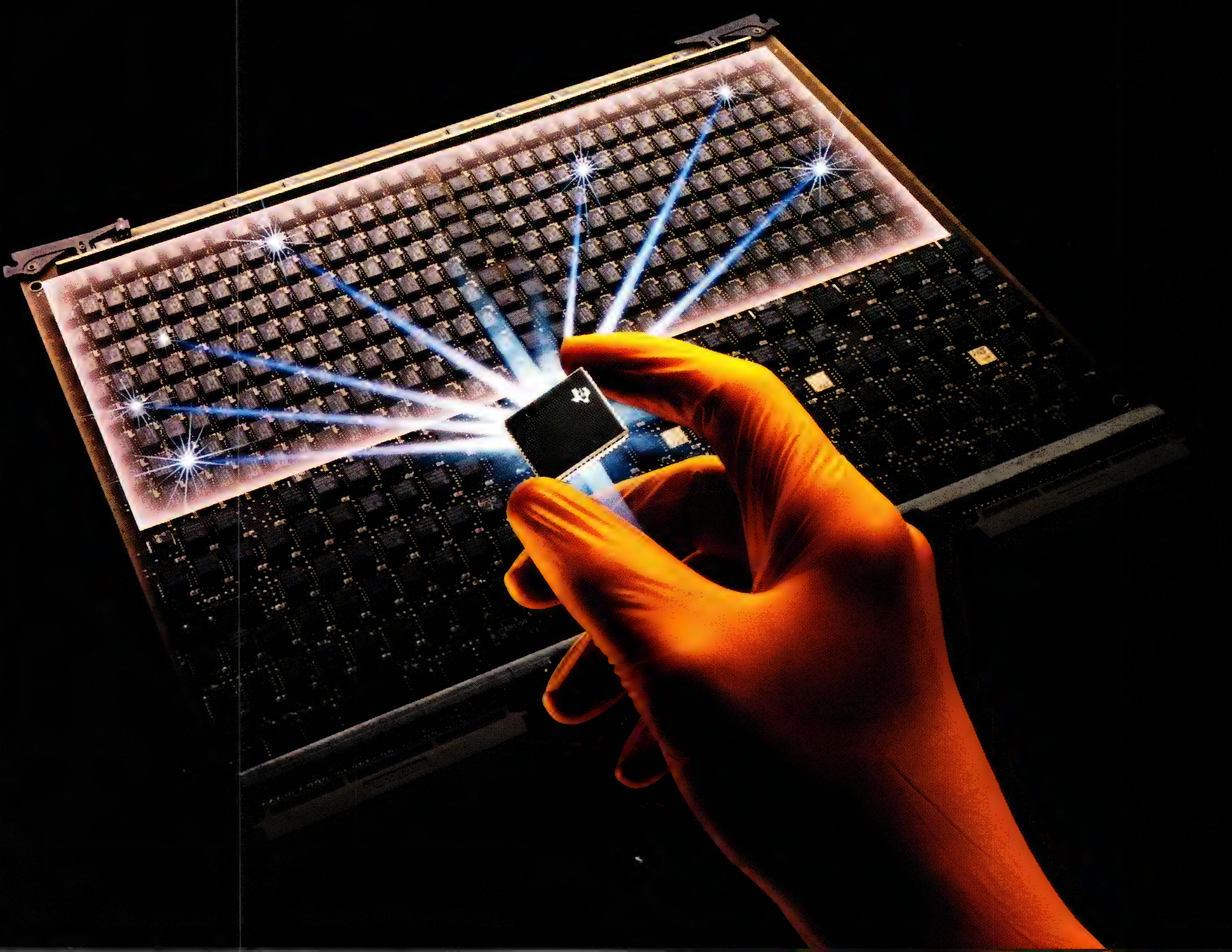
$$T = \frac{K}{D}$$

YOUR TURN

EDN's Signals and Noise column provides a forum for readers to express their opinions on issues raised in the magazine's articles or on any topic that affects the engineering industry. Send your letters to the Signals and Noise Editor, 275 Washington St, Newton, MA 02158. We welcome all comments, pro or con. All letters must be signed, but we will withhold your name upon request. We reserve the right to edit letters for space and clarity.

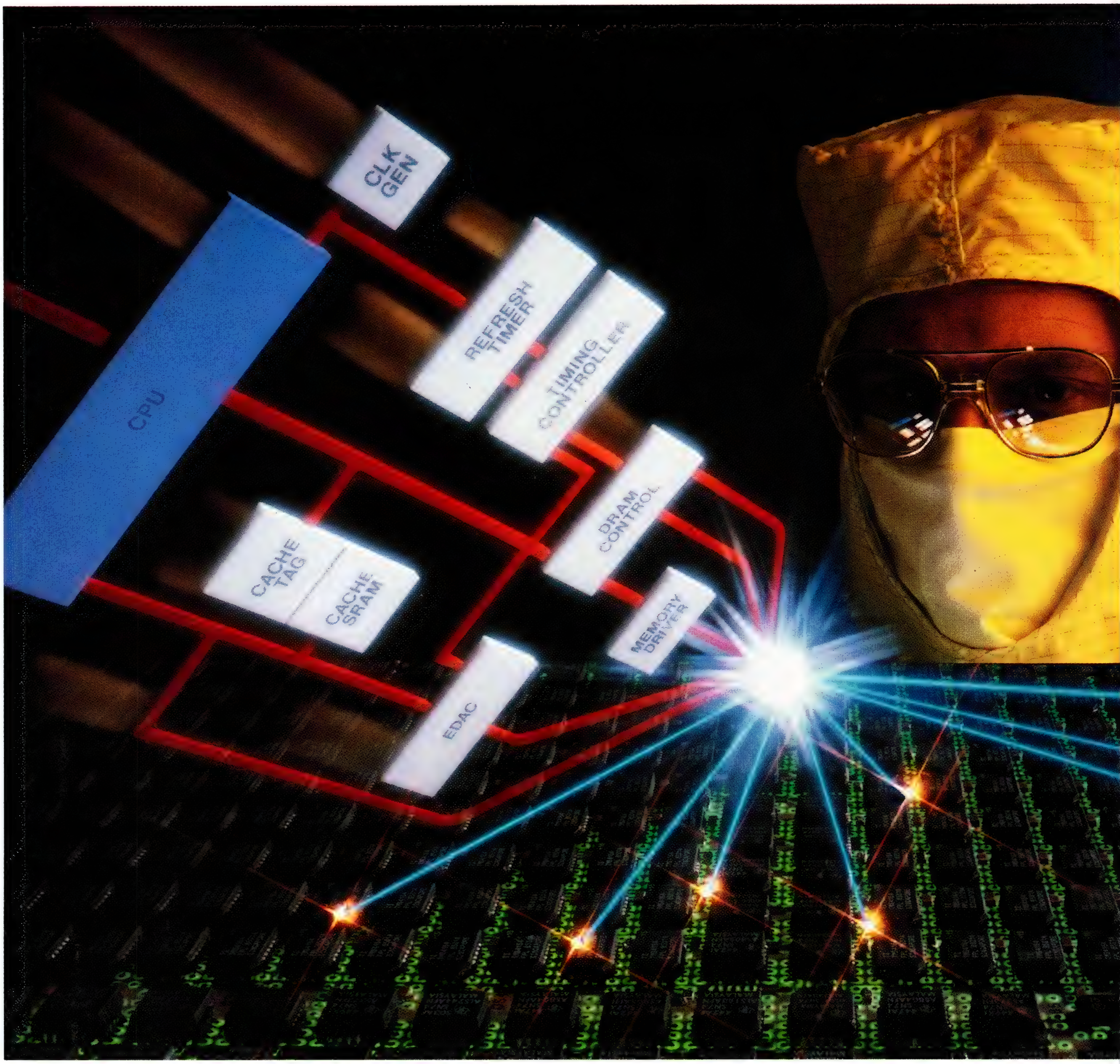
TEXAS INSTRUMENTS REPORTS ON MEMORY MANAGEMENT

IN THE ERA OF MegaChip™ TECHNOLOGIES



Memory management in the Era of MegaChip Technologies:

Memory-management ICs from
you bring memory arrays up to



Memory systems are a prime area for significant improvements in overall system throughput. Read how TI's memory-management ICs can get you in and out of memory faster no matter which processor you choose.

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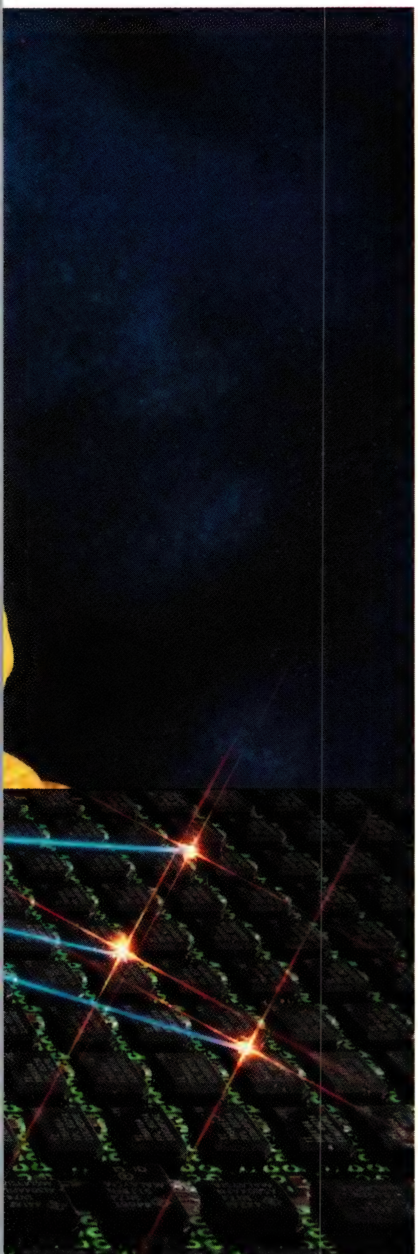
Iexas Instruments can help processor speeds.



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To immediately improve memory-access time, use both main and cache memories, as shown in the block diagram. This approach can produce up to a 3X increase in system performance.

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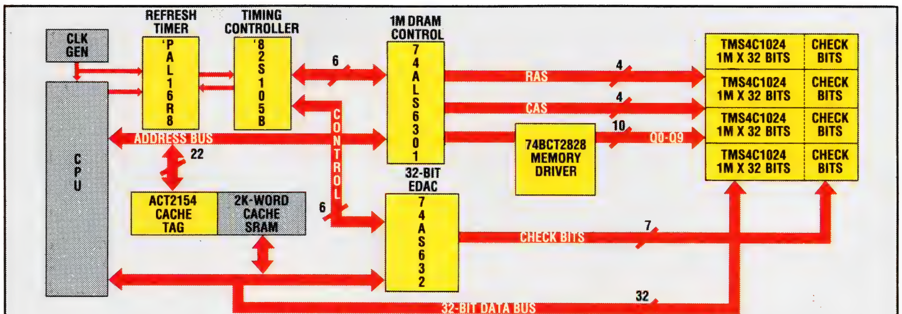

High-speed memories can be designed with less effort and implemented more cost-effectively by using TI's family of universal memory-management ICs. These devices, all of which are contained in TI's Memory Management Design Kit, will work with and enhance almost any high-speed processor.

This scheme is cost-effective because slower, less expensive dynamic random-access memories (DRAMs) can be used for main memory.

When you must assure system integrity, use of an error-detection-and-correction (EDAC) circuit can improve system reliability 500-fold. Since this approach is necessary with memory arrays larger than half a million bits, TI offers its leadership 32-bit EDAC.

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▶ *Turn page for more information.*

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  - —SN74AS632 32-bit EDAC
  - —SN74ALS6301 16K to 1 Mbit DRAM Controller
  - —SN74BCT2828 10-bit Buffer/Driver with series-damping resistor
  - —TIBPAL16R8-10 and TIB82S105B High-speed Programmable-logic Devices for user-defined timing control
  - —TMS4464 256K DRAM
- *Memory Management Applications Handbook* containing applications reports and briefs that supply valuable insights into memory-management system design.
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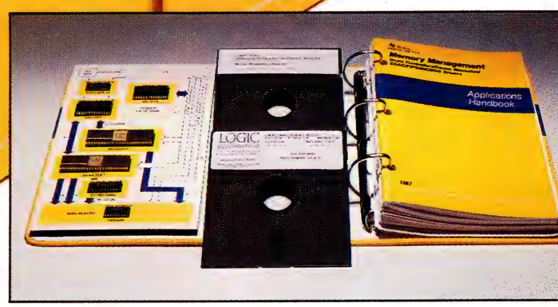
For more information on TI's Memory Management Design Kit, call 1-800-232-3200, ext. 3203, or contact your nearest TI field sales office or authorized distributor.



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YES, please send me more details on TI's universal memory-management ICs.

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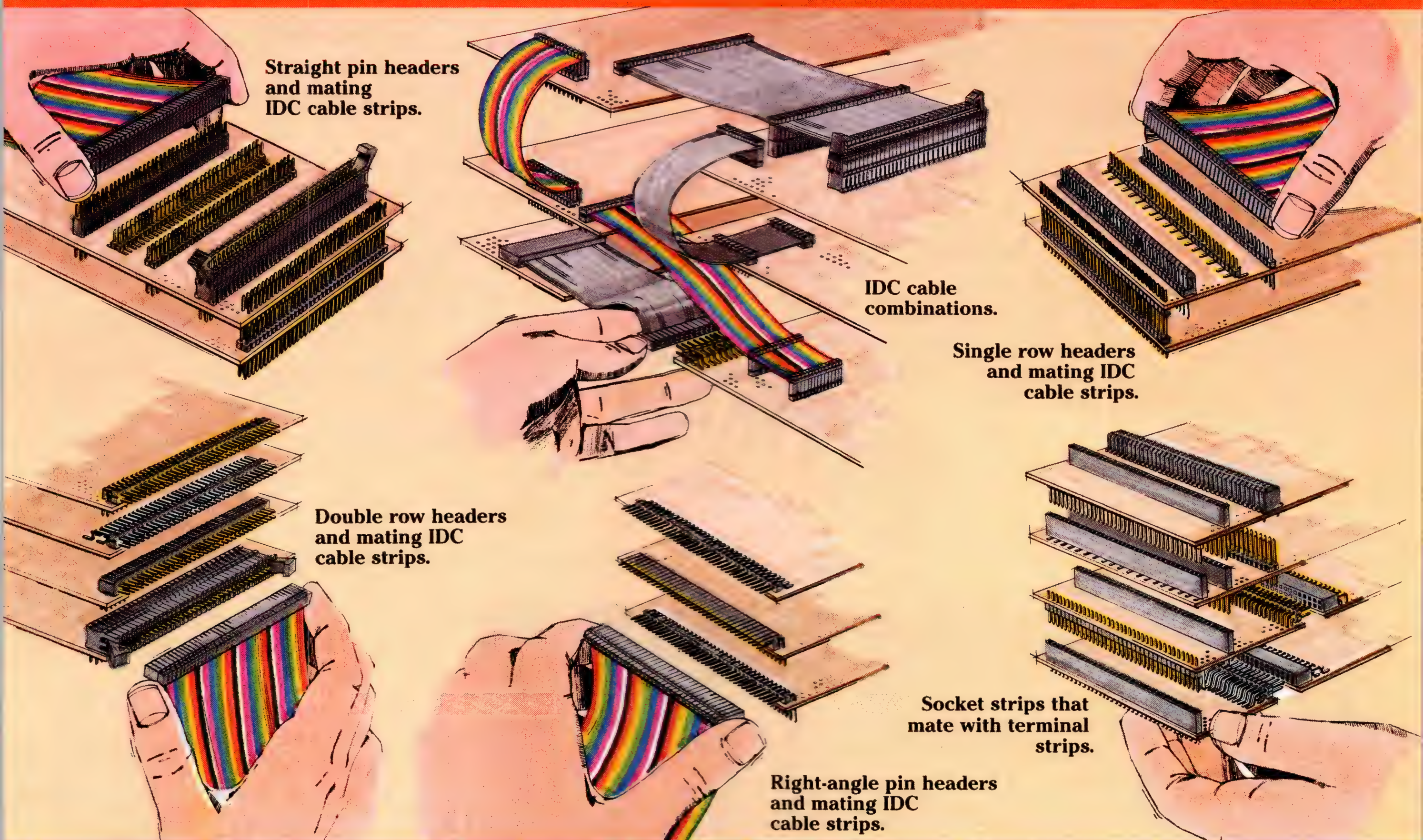

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CALENDAR

APEC '88, New Orleans, LA. IEEE Power Electronics Council, 655 15th St, NW, Suite 300, Washington, DC 20005. (202) 639-4990. February 1 to 5.

Microwave Circuit Design I (short course), El Segundo, CA. UCLA Extension, 10995 Le Conte Ave, Los Angeles, CA 90024. (213) 825-3344. February 1 to 5.

High-Performance Computer Architectures (short course), Los Angeles, CA. Integrated Computer Systems, Box 3614, Culver City, CA 90231. (800) 421-8166; in CA, (213) 417-8888. February 2 to 5.

Microwave Circuit Design II (short course), Los Angeles, CA. UCLA Extension, 10995 Le Conte Ave, Los Angeles, CA 90024. (213) 825-3344. February 8 to 12.

Unix Technical Conference, Dallas, TX. Usenix Conference Office, Box 385, Sunset Beach, CA 90742. (213) 592-1381. February 9 to 12.

American Association for the Advancement of Science Annual Conference, Boston, MA. AAAS, 1333 H St NW, Washington, DC 20005. (202) 326-6448. February 11 to 15.

Semicustom Circuit Program Conference, San Diego, CA. Mackintosh Consultants, 209 W Central St, Natick, MA 01760. (617) 655-0001. February 17 to 19.

Software Development '88, San Francisco, CA. Miller Freeman Publications, 500 Howard St, San Francisco, CA 94105. (415) 995-2426. February 17 to 19.

Digital Signal Microprocessor and Microcomputer Chips and Development Systems (seminar), Palo Alto, CA. Amnon Aliphas, DSP Associates, 18 Peregrine Rd, Newton, MA 02159. (617) 964-3817. February 22 to 24.

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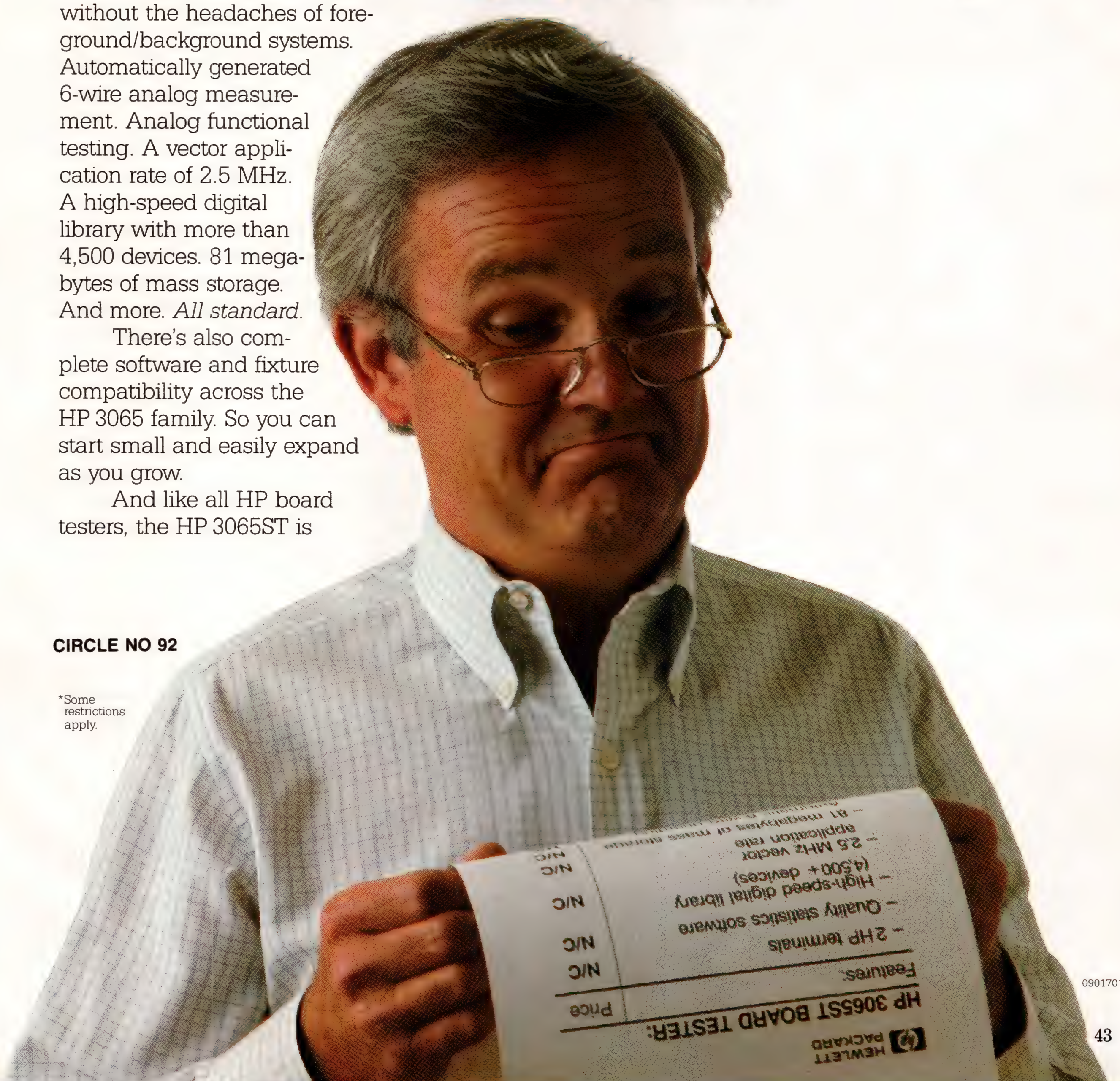

CIRCLE NO 92

*Some restrictions apply.

0901701

CALENDAR

Compcon Spring '88 (33rd IEEE Computer Society International Conference), San Francisco, CA. Hasan AlKhatib, Dept of EECS, Santa Clara University, Santa Clara, CA 95053. (408) 927-1818. February 29 to March 4.

Personal Computer Interfacing for Scientific Instrumentation Automation (short course), Blacksburg, VA. Linda Leffel, CEC, Virginia Tech, Blacksburg, VA 24061. (703) 961-4848. March 10 to 12.

Modern Electronic Packaging (seminar), San Diego, CA. Technology Seminars, Box 487, Lutherville, MD 21093. (301) 269-4102. March 15 to 17.

Neural Networks for Artificial Intelligence, Arlington, VA. Technology Transfer Institute, 741 10th St, Santa Monica, CA 90402. (213) 394-8305. March 21 to 23.

Digital Signal Microprocessor and Microcomputer Chips and Development Systems (seminar), Cambridge, MA. Amnon Aliphas, DSP Associates, 18 Peregrine Rd, Newton, MA 02159. (617) 964-3817. April 4 to 6.

American Power Conference, Chicago, IL. Robert Porter, Chicago Institute of Technology, Chicago, IL 60618. (312) 567-3202. April 18 to 20.

Instrument Society of America/IEEE Columbus Conference and Exhibit, Columbus, OH. Sol Black, AT&T Network Systems, Dept 11CB123430, 6200 E Broad St, Columbus, OH 43213. (614) 860-5605. April 19 to 20.

IEEE Instrumentation/Measurement Technology Conference (IMtc/88), San Diego, CA. Bob Myers, IMtc, 1700 Westwood Blvd, Los Angeles, CA 90024. (213) 475-4571. April 19 to 22.

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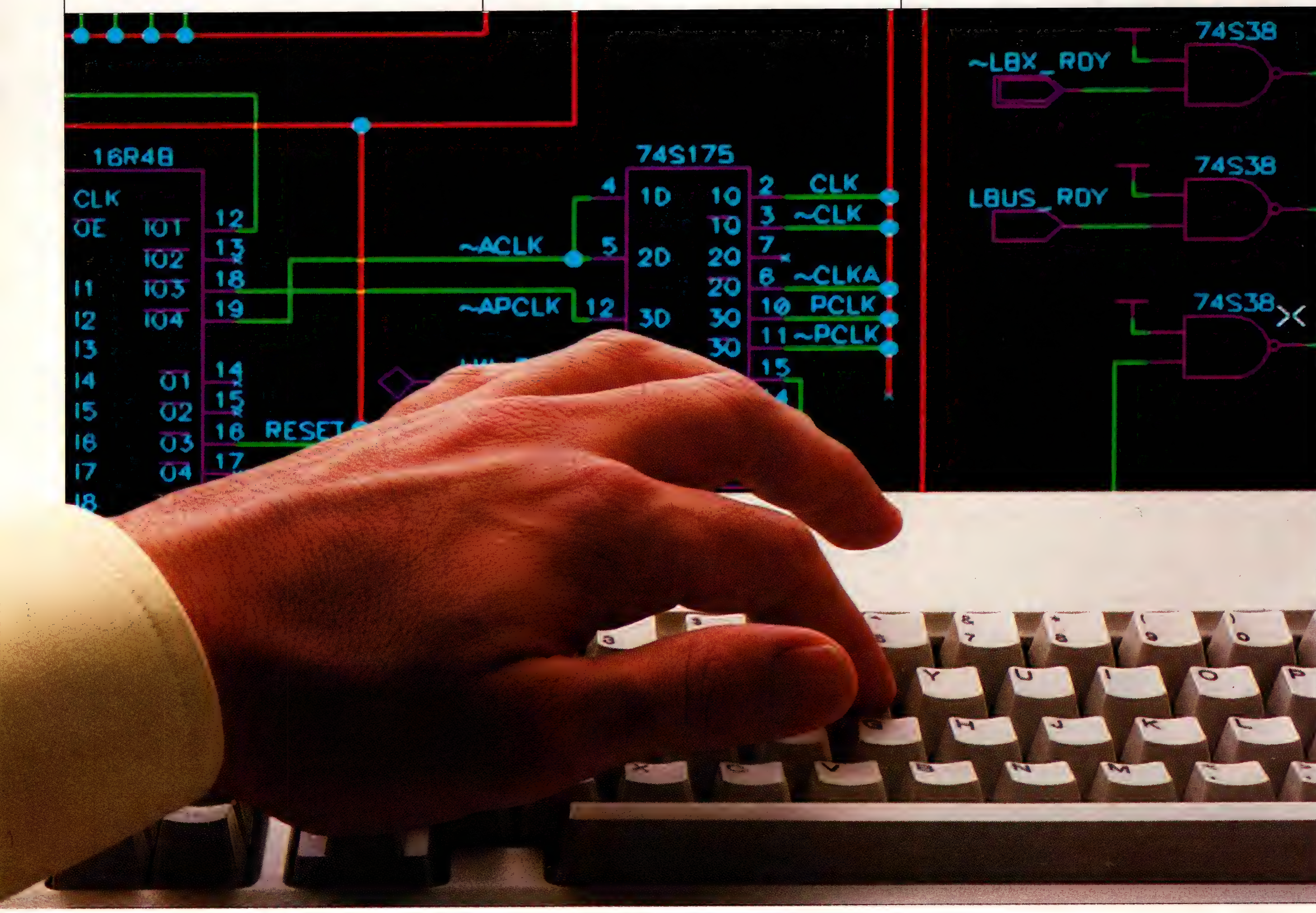

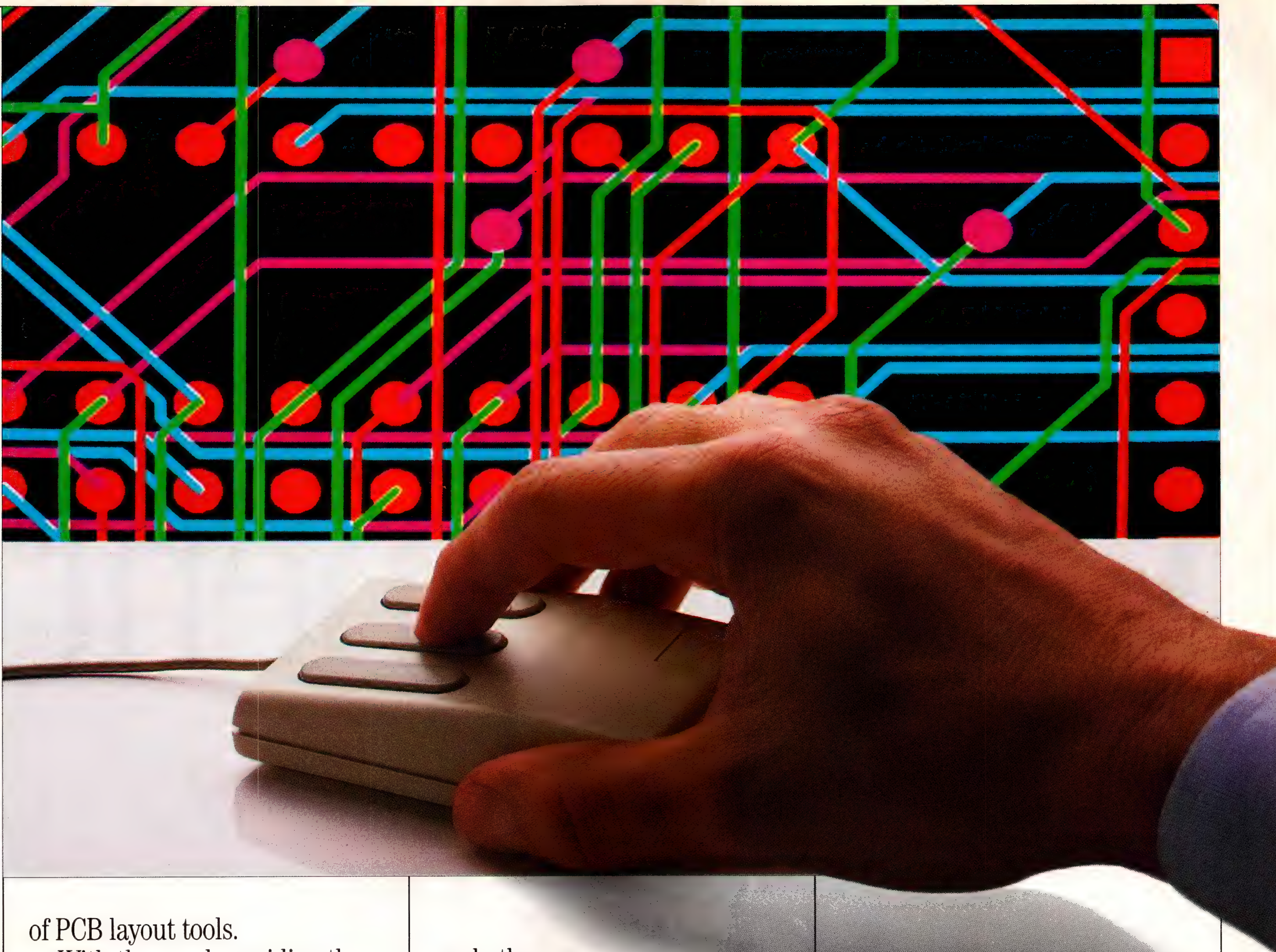

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EDITORIAL

Stamp out design snobbery

KEEPING AMERICA COMPETITIVE

Because of the way many companies regard manufacturing, several American electronics sectors have lost their ability to manufacture competitive products. They assume that if engineering can create a product, and marketing and sales can sell it, getting it built won't be a problem. Conventional wisdom says that manufacturing (which includes test in most companies) doesn't require skills as valuable as those needed for management or design. This attitude develops in future engineers while they're still in college and contemplating career alternatives. Few students are taught to regard manufacturing—if it's mentioned at all—as highly as design. As a result, most view manufacturing as a job for those who "can't make it" in design.

For American electronics companies to survive and succeed in today's competitive markets, manufacturing professionals must receive their due. That means elevating them to the same status within their companies that their counterparts in design have. The argument that "we can't afford it" is specious—it's pretty easy to make the case that we can't afford to do anything else.

It's an oversimplification to blame all our competitiveness problems on the second-class rewards given to most technical professionals in manufacturing. But the existing system continues to drive a substantial portion of electronics manufacturing out of the United States. Clearly, a change in attitudes and pay structures can't happen overnight. Indeed, if we raise salaries without a corresponding improvement in manufacturing-engineering skills, we'll simply increase the cost of American-made products. That's the opposite of the desired effect.

Several steps hold the potential for improving the situation. First, more top-notch students will opt for manufacturing-engineering careers if they're made aware of the challenges manufacturing professionals face and the skills demanded of those who pursue manufacturing careers. Colleges should call upon local industry to supply guest lecturers with manufacturing-engineering backgrounds who can bring the field to life for students. Companies should offer summer employment in manufacturing to college engineering faculty—with the understanding that, back on campus, the professors will weave their experiences into the courses they teach.

Manufacturing engineers should be brought into design projects early. They should be given a real voice in shaping products so that they're producible. Their mission should be to educate their design colleagues about manufacturing concerns. Many companies pay lip service to design/manufacturing partnerships, but the sad fact is that, all too often, manufacturing engineers are in these so-called partnerships to understand what design is doing, *not* to affect it. Many more engineers should follow the products they design into the manufacturing stage. Even design engineers who think they understand manufacturing are likely to develop an entirely new perspective after they've spent a year with the day-to-day problems they had a hand in creating. That perspective will make the next product they design much more manufacturable.

Dan Strassberg
Associate Editor

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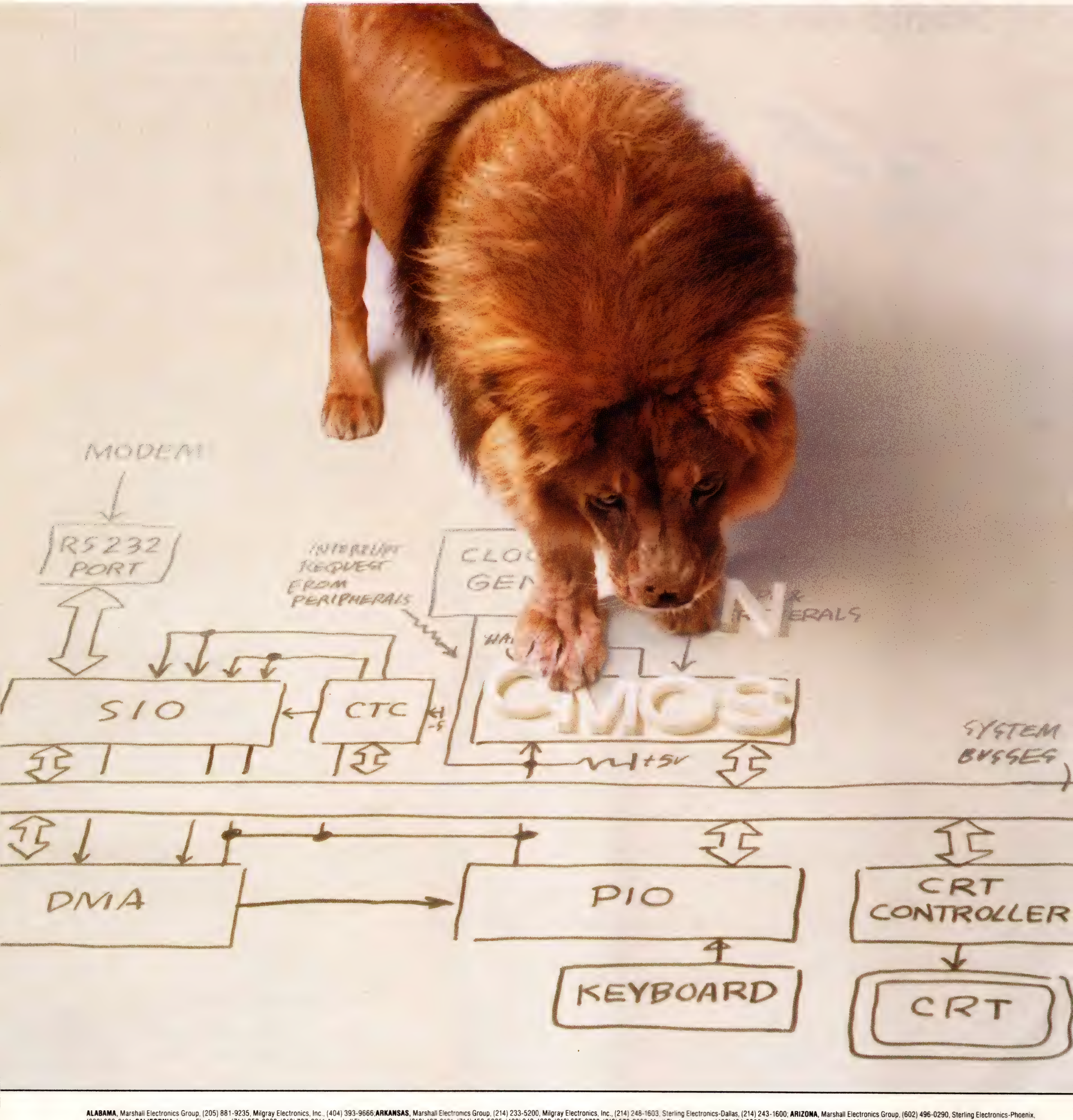

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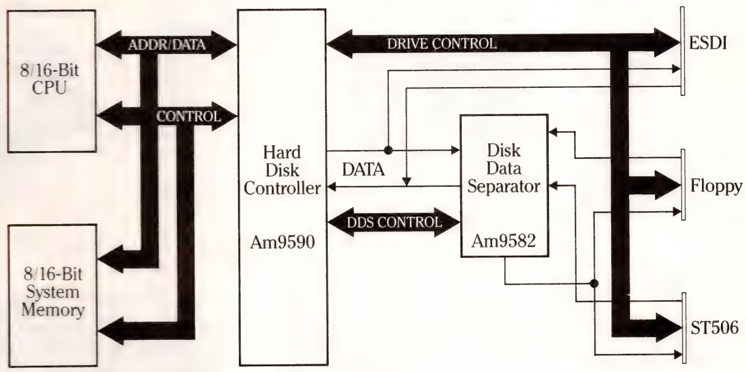

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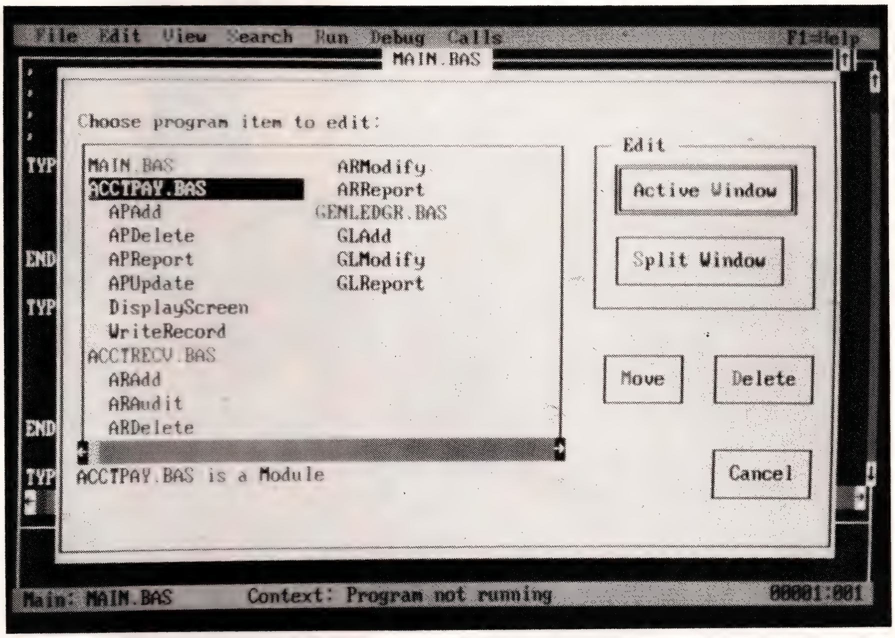
C interpreters and incremental compilers function as interactive development tools

Chris Terry, *Associate Editor*



Integrated development tools let you move *from one component to another very easily. You can perform all the tasks of development without going back to the DOS command level. (Photo courtesy Microsoft)*

If you've been thinking of switching from Basic to C for your ad hoc programs, but have been discouraged by compilers and their tedious edit-compile-link-run cycles, interactive C packages may provide the incentive you need.

Since 1985, several good C interpreters have been available that provide convenient interactive program development, but unfortunately they execute your programs rather slowly. More recently, the technique of incremental compilation has spawned inexpensive C development packages that provide all the power of C and retain both the convenience of an interpreter and the execution speed of compiled C. These interactive packages make it easy to learn C (or to become more fluent in it) and provide a great deal of help in the development process.

Compiling happens only once

Taking a look at the differences between compilers and interpreters will help you to understand the benefits that these development packages have to offer. Both compilers and interpreters are programs that translate high-level language (HLL) statements into machine code that your computer can execute.

A compiler does its translating just once; its input is a file (which you create with an editor) that contains your HLL statements. The compiler analyzes these statements and generates either assembly-language or machine code. If it generates assembly-language code, you must perform the additional step of translating the assembly-language statements to machine code with the aid of an assembler program.

In either case, the memory addresses contained in the machine code are incomplete and don't take into account the subroutines contained in the external libraries. The final step of combining standard functions (such as I/O) from the external libraries is performed with a linker program; the result is a complete program that you can load and run.

The compiled code is relatively compact because it consists only of the routines you've written, plus the specific library routines that your program needs. It is also fast, because the processor executes machine-code instructions at full speed—it doesn't have to spend time on the translation process.

The debugging process, however, is tedious. If the compiler, the assembler, or the linker detects an error, the process halts and sends you back to the operating system. You then have to go back to the editor to correct your HLL source code and then recompile, reassemble, and relink the program. Moreover, you may have to repeat this process several times. A simple syntax error can take you anywhere from five minutes to a half-hour to correct, depending on the size of your program and on how fast the compiler and the linker operate.

With an interpreter, you get immediate feedback on what you've done wrong, and you can rerun the program as soon as you've corrected the error. Interpreter packages include a built-in editor, which allows you to enter your HLL statements and then run them without leaving the program; if the interpreter detects an error, it halts and puts you back into the edit mode so that you can correct it.

To help in debugging, you can add PRINT statements that let you

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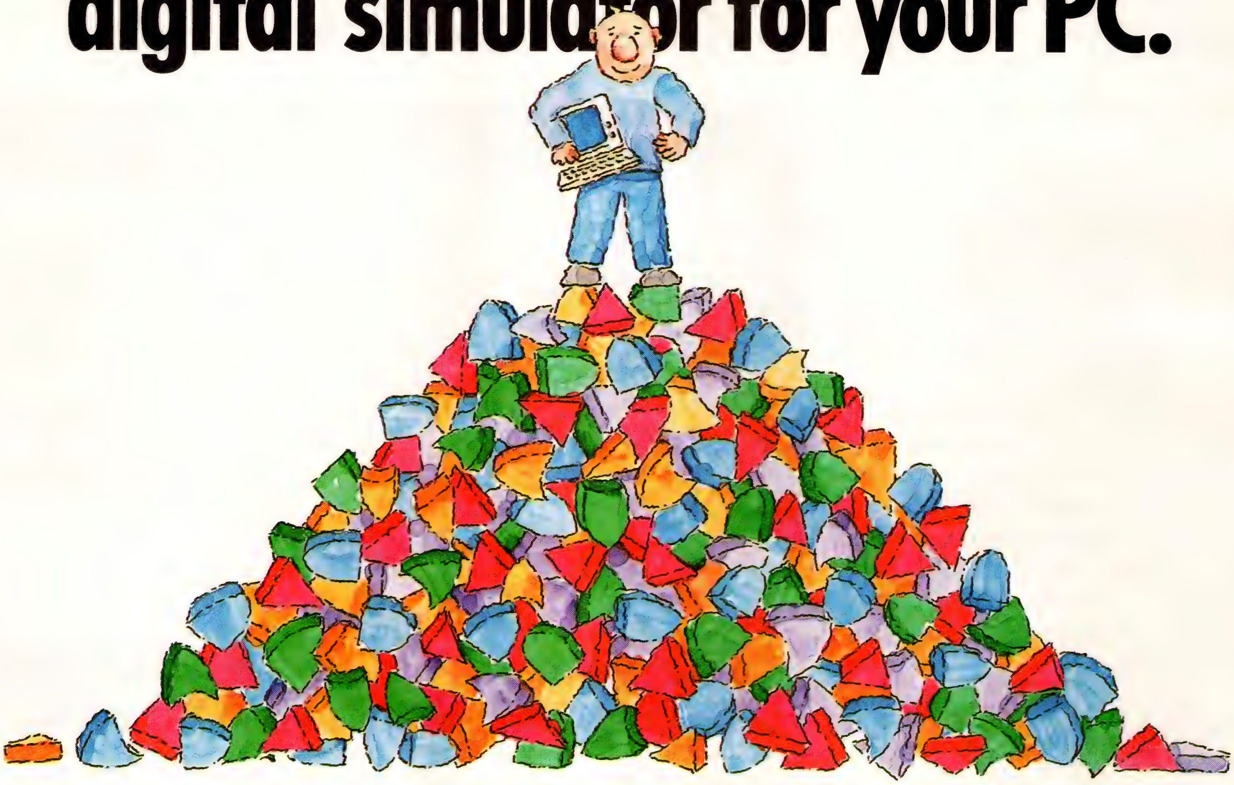

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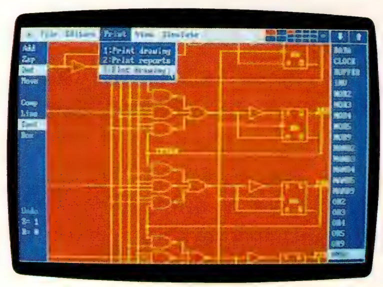

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keep track of the progress of the program and the changing values of your variables. Many interpreters include a TRACE statement that shows you exactly what lines of code are being executed at any moment; this feature helps you find anomalous branches and sections of code that never get executed. The process of writing, running, correcting, and rerunning a program is fast and convenient because you never have to leave the interpreter package.

There's a tradeoff, of course. The interpreter has to translate each HLL statement each time it comes to that statement during program execution. For instance, if your program makes 1000 passes through a loop, theoretically each statement in the loop has to be translated 1000 times. Although clever interpreters are capable of some shortcuts, your program will still execute much, much more slowly than will an equivalent program written in assembly language or compiled from HLL source code.

There's another snag, too. A complete interpreter package (26k bytes for BasicA) must be present in memory before you can run your program. If the program is small, there's no problem, but if you have a big program, the extra bytes may cause you to run out of memory.

In the beginning

The first interpretive languages were APL (A Programming Language), developed under the auspices of IBM, and Basic (Beginner's All-purpose Symbolic Instruction Code), developed at Dartmouth College. Scientists and engineers greeted both languages with enthusiasm.

APL is primarily an array manipulator, and it is powerful and fast. However, it uses a strange and complex set of symbols, available on a special golf ball for IBM Selectric computer terminals, but difficult to simulate on ASCII screens and keyboards. It's definitely not "user friendly," and nowadays it has only a small—albeit devoted—following.

Basic, on the other hand, uses the standard ASCII character set. It handles numbers reasonably well (the precision you can achieve depends on the implementation), and it has good string facilities—which is important when you want your program to provide helpful messages and menus. It is so easy to learn that it has become the de facto language for personal computers, and it has engendered many dialects, some of which have special commands that are useful for instrumentation and process control.

The best of both worlds

Efficient Basic compilers alleviate the problem of slow program execution. You can develop and debug your programs using an interpreter, and then compile the final version of your code, which will execute 50 to 100 times faster.

In the majority of implementations, however, the most important disadvantage of Basic is still present: All variables are global. If you inadvertently use the same variable name for two different purposes, you may lose important intermediate results because the second process changes values that should have been preserved.

Also, no restriction applies to the use of the GOTO branch instruction. It's all too easy to write "spaghetti code" that's difficult for the writer to comprehend after a few weeks and that's almost impossible for any other programmer to maintain.

Although C isn't as easy to learn as Basic, it lets you manipulate the hardware and it helps you to write well-structured programs. Moreover, beginning two years ago, C interpreters began to appear that help you develop C programs as easily as Basic programs.

Two of the best of these are Gimpel Software's C-terp, which costs \$298, and Lifeboat Associates' Run/C Professional, which sells for \$250. Both packages have a built-in editor as well as an interpreter, and they allow you to enter (and save) source code and then run and debug your program interactively.

Both of the packages let you load and automatically link libraries of functions that you have previously compiled, or that are available commercially. Separate versions of C-terp are available for use with the compilers (and libraries) supplied by Microsoft, Lattice (Lombard, IL), the C-86 from Computer Innovations (Tinton Falls, NJ), and Mark Williams (Chicago, IL). Another version is compatible with Turbo C from Borland International.

You may be able to use many of the functions contained in libraries from other sources; however, because of slight differences in the way compilers handle some functions, you may encounter unexpected results if you use libraries other than those that support the compiler to which your version of C-terp is matched.

The debugging facilities in the latest version—3.0—of C-terp let you display the contents of arrays, structures, unions, and even subarrays. You can set a watch condition that will halt the program and display relevant parameters when that condition becomes true. You can also execute any C expression, including function calls and expressions that set values.

Run/C Professional has a built-in editor that uses standard Wordstar commands, and it is intended for small- to medium-sized program development. Any changes that you make in the source code are immediately reflected in the tokenized code on which the interpreter operates. You can develop programs for the 8086 family's small-, medium-, and large-memory models, but not for the huge-memory model.

The package lets you load and unload, dynamically under program control, libraries that contain multiple functions. It includes libraries of math and graphics functions, as well as a library of more than 100 standard C functions. In addition, you can

load and unload not only the libraries supplied with the Microsoft and Lattice compilers, but also commercial libraries created for those compilers, such as the Greenleaf library from Greenleaf Software (Carrollton, TX).

Run/C Professional's debugging facilities allow you to set multiple breakpoints, single-step through your program, and dump variables to the screen or the printer. If the interpreter detects a syntax error, it immediately halts and returns you to the editor, placing the cursor at the point in the source code where it detected the error.

If you prefer to use your own editor, the Editor command saves your program, and then calls up the editor and loads the source code. When you finish your corrections, exiting from the editor returns you to Run/C Professional with the corrected program loaded and ready to rerun.

For those who are just getting acquainted with C and have a limited budget, there's a starter version, Run/C, for $120, that provides an editor and interpreter but much-less-extensive debugging facilities. Actually, though, the source-code-window and breakpoint facilities of Run/C Professional make the extra expenditure well worthwhile.

The interpreters described above are suitable for developing quite large and complex programs and are priced accordingly. There are several inexpensive C interpreters available, however, that have some limitations but that are useful for learning the language. If you're an Apple II user, for example, you can get Apprentice C from Manx Software for a trifling $19.

C interpreters are convenient but, like all interpreters, they're slow. Now, however, you can have a choice of an increasing number of C program-development packages, which contain an editor, an incremental compiler, and a debugger that shows you the C source code as well as the relevant sections of machine code.

These "integrated environments," as the vendors call them, give you the benefit of interactive program development, and they run programs fast and have excellent debugging facilities. Typical packages are Turbo C from Borland International ($99.95), QuickC from Microsoft ($99), and Instant C from Rational Systems ($495). Although recompiling your debugged program with a standard compiler may yield a slight advantage in terms of smaller code size or slightly faster execution, the gain isn't that significant.

Turbo C lets you use any one of six memory models so that you can suit your program to the segmented architecture of the 8086/8088 μP. You get two versions: an integrated version and a command-line version.

The integrated version uses standard Borland conventions for selecting menu items; you either move the cursor over the option you want and hit Enter, or enter a single letter that is highlighted in the option. This version makes extensive use of pop-up windows for on-line help. The menus provide shortcuts so that you can move quickly from one menu to another without going through all of the intermediate menus.

An error-tracking feature allows compilation to go as far as possible before providing a window of error messages. You can scroll through the window; if you put the cursor on a warning message, the program will show you the erroneous line in the source code. You can then switch to the source-code window, correct the error, and move back to the message window to find the next error.

This feature is much more convenient than the procedure you have to adopt with most compilers, which are all too prone to stop on the first error they detect. Reviewers have commented that Turbo C mostly generates fast, compact code. However, because the package implements the full IEEE floating-point standard with 80 bits of precision, some code may execute slowly.

QuickC's compilation takes place as soon as you've typed in a complete C statement. If the compiler detects a syntax error, it notifies you at once so that you can correct it. QuickC's debugger is a subset of Microsoft's Codeview; in the vendor's opinion, you'll rarely need all of the facilities of CodeView. However, if you select the Debug option, the program will generate information that lets you debug it with the full capabilities of the CodeView debugger. Programs developed with the aid of QuickC will in most cases run fast, but in certain applications you may be able to increase execution speed by compiling your debugged source code with the Microsoft C version 5.0 compiler.

Whereas Turbo C and QuickC are

For more information . . .

For more information on the interactive C packages discussed in this article, contact the following manufacturers directly or circle the appropriate numbers on the Information Retrieval Service card.

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PL057

CIRCLE NO 98

recently introduced products, Instant C has been available since 1985, but has undergone substantial enhancements since that first release. For Instant C 2.0, the manufacturer completely revised and greatly enlarged the documentation. The current version, 3.0, has the following additional features: function prototypes; support for the *enum* keyword that lets you define new data types; the ability to pass structures and unions as arguments; the ability to define functions that return structure- or union-values; better debugging facilities; and improved syntax checking with more helpful diagnostic messages.

In general, the enhancements bring the package into closer conformity with the new ANSI draft standard of the C language, and make it possible to use standard compilers such as Lattice and Microsoft C 5.0 to compile programs developed with Instant C. You can also make use of libraries that come with, or are created for, the standard compilers. Because the built-in editor and incremental compiler work on small modules, Instant C needs to reprocess only those parts of the program that you've actually changed, in contrast to a regular compiler, which would have to reprocess all of the source code files that make up your program.

The convenience, friendliness, and speed of these new integrated-environment packages make it well worth your while to dabble with a new language: You can experiment for a minimal amount of money, and you can try serious program development for a moderate cash outlay. If you try one of these packages, you'll probably find it addictive—and it may even entice you away from Basic or Pascal. **EDN**

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Phil F. Walters
Marketing Director
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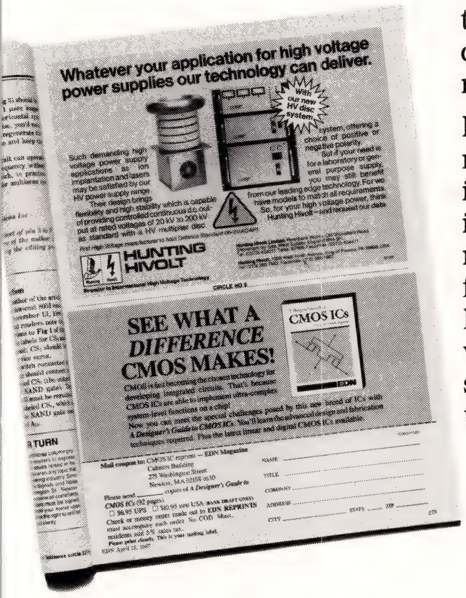

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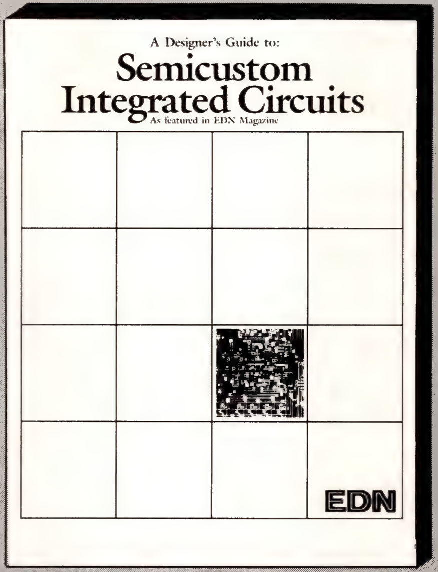

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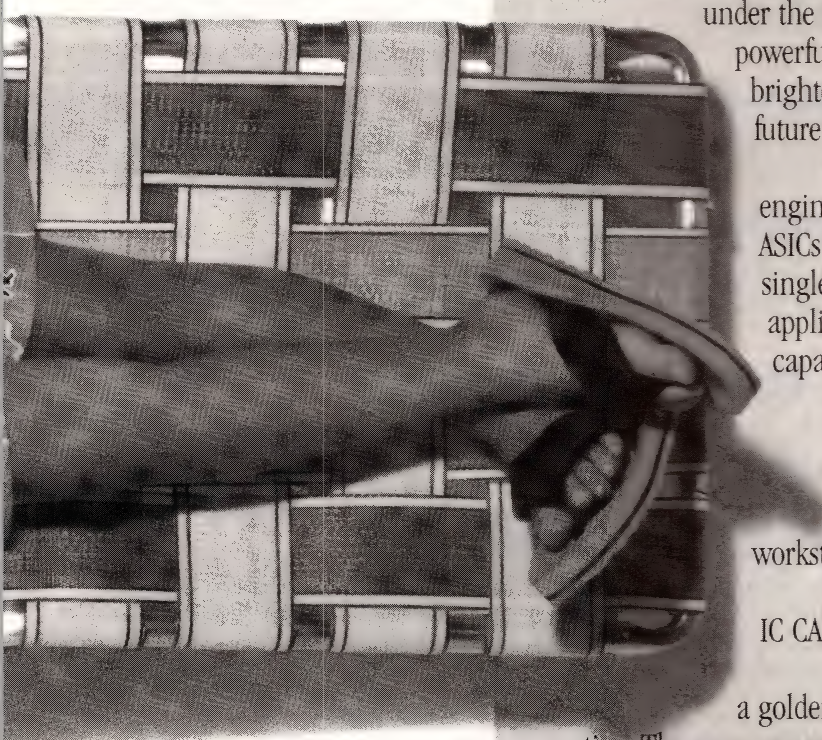

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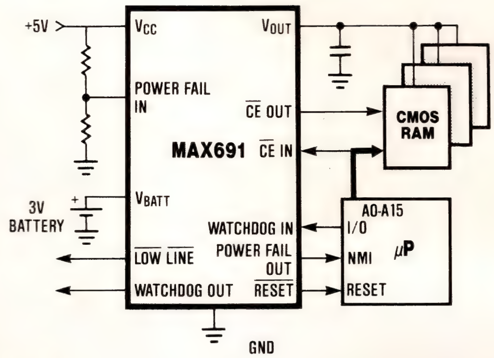

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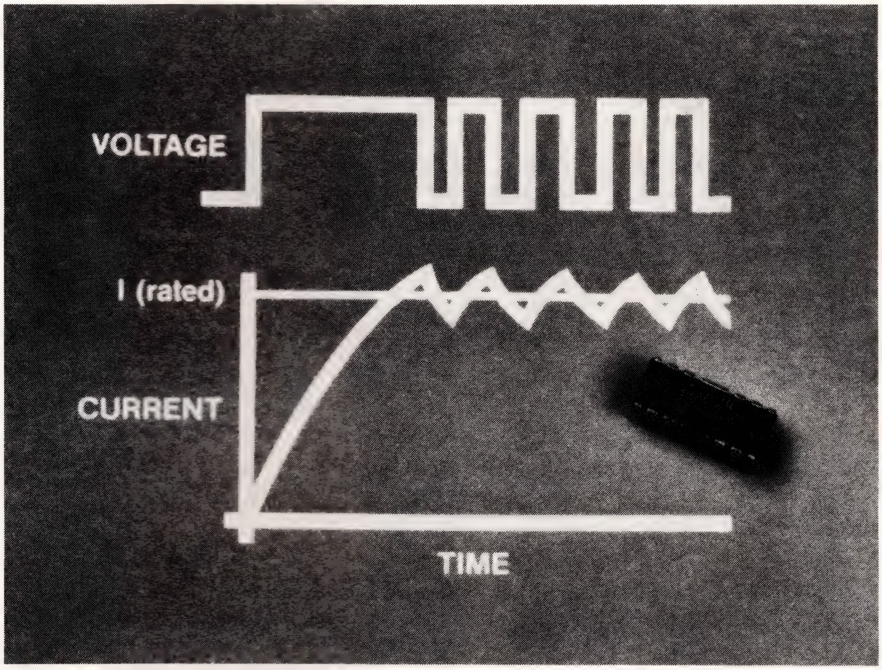
Monolithic stepper-motor drivers achieve higher power levels and greater versatility

Peter Harold, *European Editor*



***The output-current waveform** generated by Unitrode's UC3717 stepper-motor driver is typical of monostable controlled switch-mode current regulators. The transistors in the H-Bridge output are switched so that current decay in the motor winding is slow, minimizing current ripple.*

Mixed-technology processes that allow semiconductor manufacturers to integrate bipolar power transistors, analog circuitry, and logic gates on a single piece of silicon have spawned a generation of stepper-motor driver ICs that can directly drive a motor's windings yet provide a logic-level interface to a μP. Because these chips give you precise control of the current in the motor's windings via analog inputs to the driver or on-chip D/A converters, they let you microstep motors to achieve greater positional resolution and smoother motor torque than you can obtain with traditional full- or half-stepping techniques.

They also allow for switch-mode control of the winding current, which reduces power dissipation, allowing devices housed in DIPs to deliver as much as 2.0A at motor-supply voltages as high as 50V. And you don't always have to write machine code for a μP to control these stepper-motor drivers: You can obtain dedicated microcontrollers that let you use high-level commands to implement complex motor rotations.

Because it's now possible to integrate a 40 to 50V H-bridge output stage in a stepper-motor driver IC, most of the latest 1-chip stepper-motor drivers are designed to drive bipolar stepper motors. (Bipolar stepper motors, because of their single winding around each stator pole, have lower winding resistance—and therefore a lower internal temperature rise—than equivalent-torque unipolar motors with two bifilar windings.) Thermal-overload protection is also virtually standard on all the new devices.

The most common function you'll find alongside the H-bridge driver in a stepper-motor driver IC is a switch-mode current regulator that controls the current in the stepper-motor winding. This regulator comprises a comparator and either a monostable multivibrator or a set-reset latch.

When the H-bridge driver switches the supply voltage across a motor winding, the current in the winding increases linearly according to the motor's L/R time constant. When this current reaches the level set by the comparator's reference input, the comparator output changes state and triggers the monostable multivibrator or resets the latch. During the following period—which is determined either by the monostable's timing components or by the time before a clock pulse sets the latch again—the H-bridge output turns off, allowing the motor current to decay. After this period, the H-bridge output turns on again, allowing the winding current to rise again to the comparator's threshold level. This cycle repeats itself, maintaining the average winding current at the required level.

You can control the amount of ripple current in the winding by altering the monostable's period or, in the case of a latch-controlled regulator, by altering the clock frequency. One advantage of the latch-controlled current regulator is that it's easy to slave the regulators in several drivers to a master oscillator —eliminating the possibility of intermodulation effects. It's important to control the ripple current in the motor's windings: Excessive ripple current may lead to unacceptable temperature rise in the motor because of hysteresis losses in its magnetic circuit. To minimize this problem, you should choose a stepper motor with low hysteresis loss.

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CIRCLE NO 121

If you want to add switch-mode current control to a discrete driver stage—for example, because you require output currents greater than you can obtain in an integrated device—consider using SGS-Thomson Microelectronic's L6506. This device, which comes in an 18-pin DIP, contains current-sense comparators and switch-mode control logic for both windings of a bipolar stepper motor or all four windings of a unipolar motor. Its RC-controlled on-chip oscillator and set-reset latches allow it to achieve a constant switching frequency. You can easily synchronize several of the devices to one chip's oscillator.

A typical example of an H-bridge stepper-motor driver with integrated switch-mode current regulation is the industry-standard 3717, which is available from several manufacturers (**Table 1** lists the relevant specs for a number of representative stepper-motor driver ICs). As **Fig 1** illustrates, this current regulator actually incorporates three comparators and a resistive voltage divider to provide three different current levels. Two logic-level inputs, I_0 and I_1, let you digitally select any one of the three current levels or a zero-current condition. In fact, the resistive divider, comparators, and select logic amount to an on-chip, 2-bit D/A converter, although you won't find it referred to as such in a 3717 data sheet. This D/A converter has nonlinear steps that provide you with winding currents that are 0, 20, 60, and 100% of the maximum current level. The maximum level is determined by the value of the current-sense resistor and the reference-voltage input to the resistive divider.

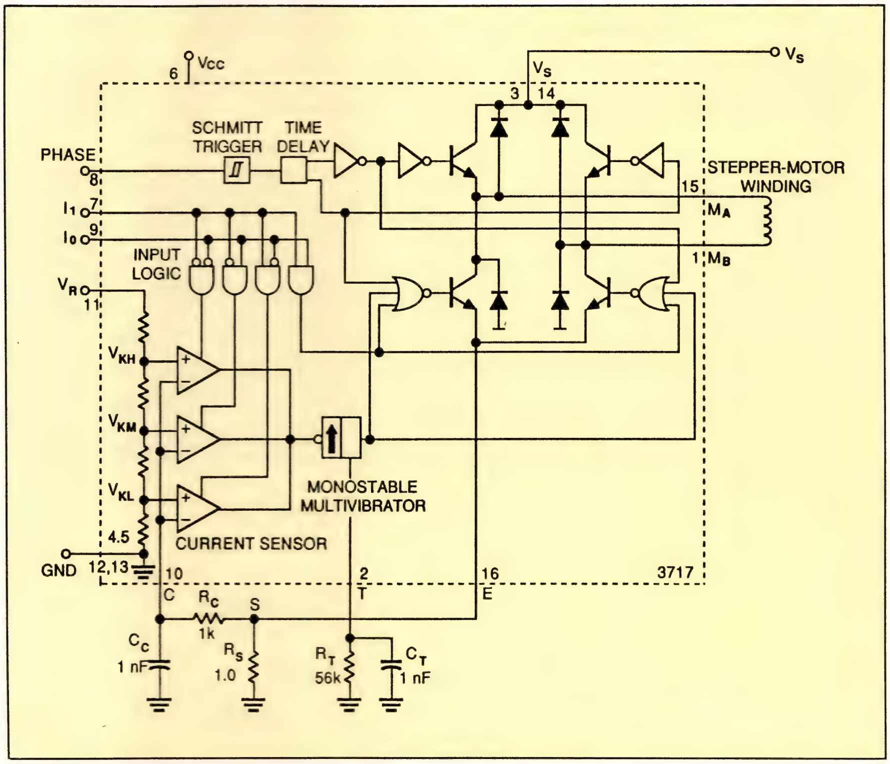

*Fig 1—**The three comparators** and select logic in a 3717 stepper-motor driver allow you to develop constant torque when you half-step the motor, or let you reduce power dissipation when the motor is stationary. By driving the reference input (V_R) with a D/A converter, you can microstep the motor.*

Matched currents smooth torque

Together with its phase input, which determines the direction of current flow in the H-bridge output stage, the 3717's 2-bit D/A converter, although simple, gives the driver IC considerable versatility. Two 3717s, each controlling the current in one of the phases of a 2-phase bipolar stepper motor, allow you to implement 1-phase-on or 2-phase-on full-step operations, and half-step operations (**Ref 1**).

During half-step operations, you use the I_0 and I_1 inputs to select 100% winding current when only one phase is on (that is, when the rotor is aligned with a stator pole), and 60% winding current when both phases are on (when the rotor is halfway between stator poles). The 60% current in both phase windings when the rotor is halfway between stator poles provides approximately the same motor torque as does the 100% current in the one winding that's energized when the rotor is aligned with a stator pole. As a result, the motor provides constant torque between all eight positions in its half-step sequence. You can also use the lower current levels to reduce power dissipation in the motor when it's stationary, provided that the motor's mechanical load has a holding-torque requirement that's lower than its dynamic-torque requirement.

Most manufacturers have taken advantage of the improved process technologies to update their 3717-type drivers. **Table 1** lists several upgraded devices with greater output-current capability, lower output saturation voltage, and higher motor-supply voltages than the original 3717. (Rifa's PBL3717 is an example of a device built to the original specification.) Cherry Semiconductor's CS3770, for example, is a high-power version of a 3717 with a continuous output-current rating of 1.2A and a low output-saturation voltage of 2.0V at 0.8A. The CS3770 is an alternate source for the Rifa PBL3770. However, while Cherry Semiconductor has been developing the CS3770, Rifa has upgraded its part: The upgrade, the PBL3770A, not only increases the continuous output current capacity to 1.5A, but also overcomes a potential step-rate problem with all 3717s and similar drivers.

Text continued on pg 74

TABLE 1—REPRESENTATIVE STEPPER-MOTOR DRIVER ICs

MANUFACTURER	DEVICE TYPE/ NUMBER	STEPPER-MOTOR TYPE[1]		NUMBER OF MOTOR PHASES (WINDINGS) CONTROLLED	ON-CHIP PHASE SEQUENCING			ON-CHIP CURRENT CONTROL	
		UNIPOLAR	BIPOLAR		FULL-STEP (1-PHASE-ON)	FULL-STEP (2-PHASE-ON)	HALF-STEP	SENSE COMPARATOR	SWITCH-MODE LOGIC
CHERRY SEMICONDUCTOR	CS3717A		•	1				•	A
	CS3770*		•	1				•	A
MIETEC	MTC6017*		•	1				•	A
	MTC6018*		•	1				•	—
RIFA	PBD3517	•		4		•	•		
	PBL3717		•	1				•	A
	PBL3717/2*		•	1				•	A
	PBL3770A*		•	1				•	A
	PBL3771*		•	2				•	S
	PBM3960*	•	•	2					
SGS-THOMSON MICROELECTRONICS	PBL3717A		•	1				•	A
	TEA3717		•	1				•	A
	TEA3718* TEA3718S*		•	1				•	A
	UAA2081*	•		8 (TWO MOTORS)					
	UAB4718* UAF4718*		•	2				•	S
	L6217*		•	2				•	A
	L6217A*		•	2				•	A
	L6506*		•	4/2				•	S
	L297, L297A		•	4/2	•	•	•	•	S
	MC3479C*		•	2		•	•		
SIEMENS	TCA1560B*		•	1				•	S
	TCA1561B*		•	1				•	S
SIGNETICS	SAA1027	•		4		•			
SPRAGUE	UDN-2953B UDN-2954W		•	1				•	A
	UDN2962-B UDN2962-W	•	•	2/1				•	H
	UDN2965-W, UDN2965-W2	•	•	2/1				•	H
	UCN4202A	•		4	•				
	UCN4203A	•		4	•				
	UCN4204B	•		4	•	•	•		
	UCN4205B-2	•		4	•	•	•		
	UCN5804B*	•		4	•	•	•		
	UCN5871-B* UCN5871-EP*		•	2	•	•	•	•	—
UNITRODE	UC3517	•		4		•	•		
	UC3717		•	1				•	A

NOTES:
1. FOR DEVICES WITH ON-CHIP DRIVERS, THIS CLASSIFICATION RELATES TO DIRECT CONNECTION TO THE STEPPER MOTOR, WITHOUT INTERMEDIATE LOGIC OR DRIVER DEVICES
2. VALUES QUOTED ARE RECOMMENDED OPERATING CONDITIONS, NOT ABSOLUTE MAXIMUM VALUES
3. ON-CHIP OUTPUT-PROTECTION DIODES ARE PROVIDED ONLY FOR THE H-BRIDGE SINK TRANSISTORS
4. LOGIC SUPPLY IS INTERNALLY GENERATED FROM DRIVER-SUPPLY VOLTAGE

D/A CONVERTER	ON-CHIP DRIVERS: MAXIMUM CURRENT/ PHASE[2]	SUPPLY-VOLTAGE RANGE[2]	TOTAL SATURATION VOLTAGE (MAX)	OUTPUT-PROTECTION DIODES	THERMAL SHUTDOWN	LOGIC-SUPPLY VOLTAGE	PACKAGE TYPE, NO OF PINS	PRICE (1000)	COMMENTS
2-BIT	1.0A	10 TO 46V	5.1V AT 1.0A	•	•	5V	DIP, 16	$1.16	
2-BIT	1.2A	10 TO 40V	2.0V AT 0.8A	•[3]	•	5V	DIP, 16	$2.15	
2-BIT	0.8A	10 TO 40V	3.5V AT 0.5A	•	•	3 TO 7V	DIP, 16	~$2.20	AVAILABLE 1ST QUARTER 1988
6-BIT	0.8A	10 TO 40V	3.5V AT 0.5A	•	•	3 TO 7V	DIP, 20	~$2.50	AVAILABLE 2ND QUARTER 1988
	0.35A	10 TO 40V	0.85V AT 0.35A			5V	DIP, 16	$1.53	HAS BILEVEL/VOLTAGE-DOUBLER DRIVE OUTPUTS AND HALF-STEP POSITION OUTPUT
2-BIT	0.8A	10 TO 40V	4.0V AT 0.5A	•	•	5V	DIP, 16	$1.33	
2-BIT	1.0A	10 TO 45V	2.9V AT 0.8A	•	•	5V	DIP, 16; PLCC, 28	$1.33	
2-BIT	1.5A	10 TO 45V	2.9V AT 1.3A	•[3]	•	5V	DIP, 16; PLCC, 28	$2.08	FAST CURRENT DECAY IN ZERO-CURRENT STATE
	0.6A	10 TO 40V	2.55V AT 0.5A	•	•	5V	DIP, 22; PLCC, 28	$4.17	ON-CHIP SWITCH-MODE FREQUENCY OSCILLATOR. FAST-CURRENT-DECAY CONTROL
TWO 7-BIT DACs						5V	DIP, 22; PLCC, 28	$3.57	GENERATES FAST-CURRENT-DECAY CONTROL FOR PBL3771. INTERFACE TO 8-BIT/μP BUS.
2-BIT	1.0A	10 TO 46V	5.1V AT 1.0A	•	•	5V	DIP, 16	$1.65	
2-BIT	1.0A	10 TO 40V	4.0V AT 0.5A	•	•	5V	DIP, 16; SIP, 15	$1.65	
2-BIT	1.2A	10 TO 45V	2.8V AT 1.0A	•	•	5V	DIP, 16; SIP, 15	$2.14	PSIP 3718 HAS THERMAL-SHUTDOWN ALARM. PSIP 3718S HAS THERMAL-SHUTDOWN PREALARM
	1.0A (1 PHASE ON), 0.7A (2 PHASES ON)	≤50V	0.9V AT 1.0A (1 PHASE ON), 1.1V AT 1.0A (2 PHASES ON)	•		4.5 TO 7V	DIP, 24	$4.29	HAS BILEVEL/VOLTAGE-DOUBLER DRIVE OUTPUTS; ON-CHIP DECODER PROVIDES BINARY-CODED STEP SEQUENCING
	1.5A (1 PHASE ON) 0.9A (2 PHASES ON)	10 TO 55V	2.6V TYP AT 1.0A	•	•	5V	SIP, 15	(UAB4718) $5.80 (UAF4718) PRICE ON REQUEST	TEMP RANGES: UAB4718, 0 TO 70°C; UAF4718, −40 TO +85°C; ON-CHIP DECODER PROVIDES BINARY-CODED STEP SEQUENCING
TWO 6-BIT DACs	0.4A	8 TO 16V	3.3V AT 0.4A	•	•	5V	PLCC, 44	~$4.00	INTERFACES TO AN 8-BIT μP BUS
TWO 7-BIT DACs	0.4A	8 TO 16V	3.3V AT 0.4A	•	•	5V	PLCC, 44	~$4.50	INTERFACES TO AN 8-BIT μP BUS
						5V	DIP, 18	$1.00	ON-CHIP SWITCH-MODE FREQUENCY OSCILLATOR.
						4.75 TO 7V	DIP, 20	$2.75	-A VERSION HAS STEP PULSE DOUBLER
	0.35A	7.2 TO 16V	2.8V AT 0.35A	•		[4]	DIP, 16	$2.20	RESISTOR-PROGRAMMABLE MAX SINK CURRENT
	1.0A	8 TO 40V	3.3V AT 0.75A	•	•	[4]	DIP, 18	$2.50	
	2.0A	8 TO 40V	3.8V AT 1.5A	•	•	[4]	SIP, 9	$3.00	
	0.5A	9.5 TO 18V	0.7V AT 0.5A	•		9.5 TO 18V	DIP, 16	$2.20 (100)	
	2.0A	6.5 TO 50V	3.6V AT 2.0A	•	•	5V	DIP, 16 SIP, 12	$1.77 $2.02	
	3.0A	20 TO 45V	4.0V AT 3.0A	•		[4]	DIP, 16 SIP, 12	$1.85 $2.03	TWO INDEPENDENT SINK/SOURCE DRIVER PAIRS; SINK AND SOURCE DRIVER TURNED ON SIMULTANEOUSLY BY A COMMON CONTROL INPUT
	4.0A	20 TO 60V 20 TO 50V	4.2V AT 4.0A	•	•	[4]	SIP, 12	$3.80 $3.53	TWO INDEPENDENT SINK/SOURCE DRIVER PAIRS; SINK AND SOURCE DRIVER TURNED ON SIMULTANEOUSLY BY A COMMON CONTROL INPUT
	0.5A	≤15V	0.9V AT 0.5A	•		5V	DIP, 16	$1.57	DOUBLE-STEP MODE
	0.5A	≤35V	1.35V AT 0.5A	•		5V	DIP, 16	$1.69	DOUBLE-STEP MODE
	1.25A	≤15V	1.0V AT 1.25A	•	•	5V	DIP, 16	$1.57	
	1.0A	≤25V	1.25V AT 1.0A	•	•	5V	DIP, 16	$1.69	
	1.25A	≤35V	1.5V AT 1.25A	•	•	5V	DIP, 16	$2.04	
	1.0A	≤45V	2.0V AT 1.0A	•	•	5V	DIP, 22 PLCC, 44	$3.36 $3.55	
	0.35A	10 TO 40V	0.85V AT 0.5A			5V	DIP, 16	$4.30	HAS BILEVEL/VOLTAGE-DOUBLER DRIVE OUTPUTS AND HALF-STEP POSITION OUTPUT
2-BIT	0.8A	10 TO 40V	4.0V AT 0.5A	•	•	5V	DIP, 16	$2.25	

KEY:
* RECENTLY INTRODUCED
A=ASYNCHRONOUS—FREQUENCY DETERMINED BY L/R TIME CONSTANT OF MOTOR WINDING AND A MONOSTABLE PERIOD
H=ASYNCHRONOUS—FREQUENCY DETERMINED BY L/R TIME CONSTANT OF MOTOR WINDING AND COMPARATOR HYSTERESIS
S=SYNCHRONOUS—FREQUENCY DETERMINED BY AN INTERNAL OR EXTERNAL OSCILLATOR
PLCC=PLASTIC LEADED CHIP CARRIER
SIP=SINGLE-IN-LINE OR OFFSET-PIN POWER PACKAGE WITH HEAT-SINK TAB

Unless you take special precautions, a 3717 or similar driver may fail to step the motor at high half-step rates because of the way in which it achieves the zero-current output condition. When the device's I_0 and I_1 control inputs are at logical one, both sink transistors in the H-bridge output stage turn off. However, under these conditions, the current in the stepper-motor winding does not immediately fall to zero. Because the motor winding is inductive, current continues to flow through it, recirculating via one of the output-protection diodes and the H-bridge source transistor, which remains on (see **Fig 2a**). The current decay around this circuit is relatively slow, and at high step rates, recirculating current in the winding may interfere with the correct stepping of the motor.

You can overcome this problem by initiating a phase reversal, via the 3717's phase input, at the same time that you apply the I_0=I_1=1 condition. Because this phase reversal turns off the source transistor that was previously on, current in the motor winding is forced to recirculate through the motor supply via two of the output-protection diodes **(Fig 2b)**.

Under these conditions, the recirculating current is opposed by the motor-supply voltage, and current decay is more rapid. However, having to implement phase control, at the same time that you set the I_0 and I_1 inputs to the zero-current condition, may complicate your drive logic or microcontroller firmware. The control logic in Rifa's PBL3770A driver, which is pin compatible with 3717 devices, turns off all four H-bridge transistors when I_0=I_1=1, providing a fast current-decay path without requiring you to implement the phase reversal.

One minor disadvantage of using either Cherry Semiconductor's CS3770 or Rifa's PBL3770A is that the high-current-source transistor structures in the H-bridge output stage preclude the manufacturers from integrating on-chip output-protection diodes across these transistors. As a result, you'll have to provide two of the four output-protection diodes externally. The 16-pin-DIP version of SGS-Thomson Microelectronics' TEA3718 is another high-power version of the 3717, providing a continuous output current of 1.2A at motor-supply voltages as high as 45V, yet retaining all four on-chip output-protection diodes.

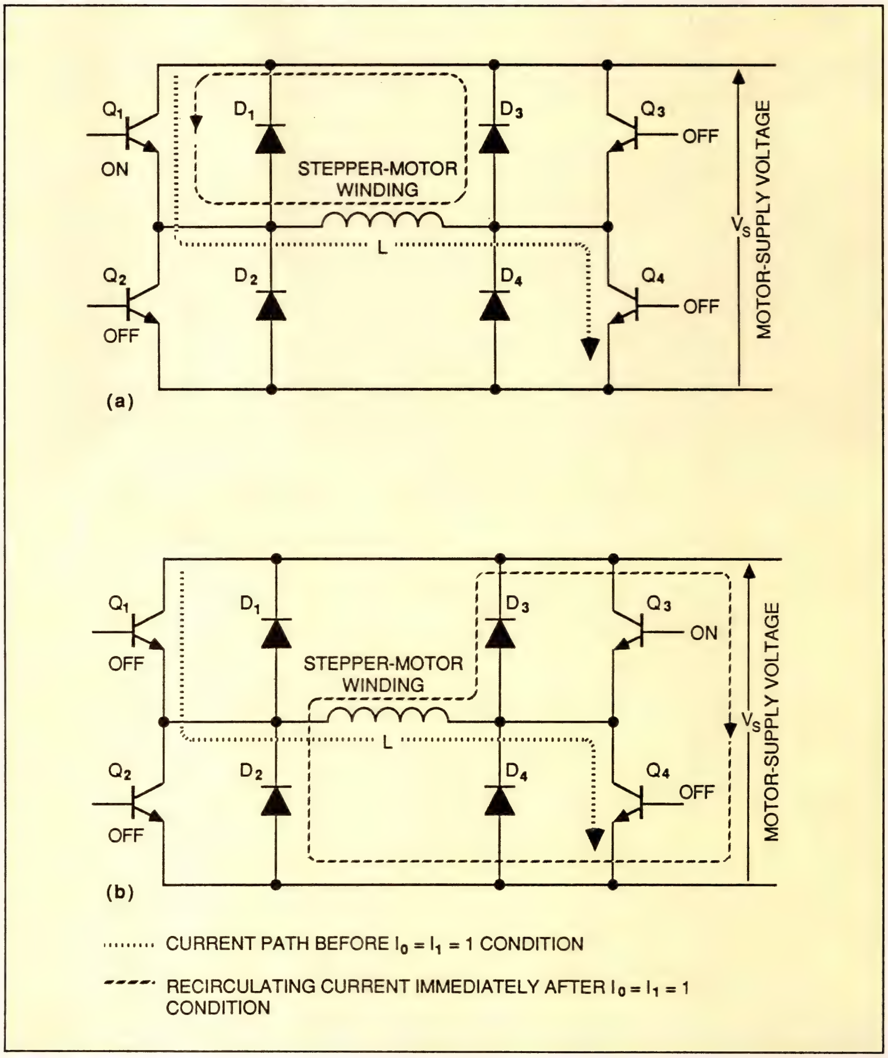

*Fig 2—**Simply selecting the zero-current condition** (I_0=I_1=1) for a 3717 driver produces a current path in which the motor's winding current decays relatively slowly **(a)**. To achieve the fast current decay required for high-speed half-stepping, you must simultaneously phase-reverse the H-bridge output stage and select the zero-current condition to establish the current path shown in **b**.*

Driver warns of overload

However, you can also obtain the TEA3718 in a 15-pin power package, and this version incorporates an open-collector alarm output that indicates when the chip goes into thermal overload. On the TEA3717 this alarm activates at the same time that the thermal-overload circuitry disables the driver. On the S-suffix version of the part, however, the alarm output is activated when the chip reaches a temperature a few degrees lower than the thermal-shutdown temperature—allowing you to take corrective action before the system malfunctions.

Another variant of the 3717, slated for introduction during the first quarter of 1988, is Mietec's MTC6017. Although this device is

pin compatible with the 3717, it has a truth table for its I_0 and I_1 inputs that provides a direct (but nonlinear) relationship between the 2-bit control code and the winding current. This direct relationship simplifies microcontroller firmware and saves you the two external inverters you'd have to use with a 3717.

The MTC6017 also incorporates an on-chip 5V reference voltage for the resistor chain that defines the three current levels in the motor winding. Although the MTC6017 will be available as an off-the-shelf product, it was originally designed for a high-volume user of stepper motors. It illustrates the lengths to which equipment manufacturers will go to reduce system complexity, a fact that's not surprising when you consider that manufacturers of low-cost computer peripherals constitute a large portion of the market for small stepper motors.

Drivers require single supply

Siemens's TCA-1560B and -1561B drivers control the current in one winding of a bipolar stepper motor; they have maximum continuous-current ratings of 1 and 2A, respectively. These devices are unusual in that the supply for their control logic is derived internally from the motor-supply voltage. If the driver is situated remotely from its control electronics, this on-chip supply reduces the cabling requirement between the two to a ground line and two TTL-level signal lines. The devices' switch-mode current regulator operates on the set/reset latch principle, allowing you to set the switching frequency locally with an RC network or synchronize it with a master oscillator.

One IC drives two motors

The latest stepper-motor drivers from the Thomson side of the SGS-Thomson alliance are the UAA2081, UAB4718, and UAF4718. The UAA2081 directly drives all windings of two independent unipolar stepper motors, each motor operating with two phases on at a current of 0.7A per phase, or with one phase on at 1.0A. To maintain a high dynamic torque, yet minimize static power dissipation in the stepper motor, you can use additional outputs on the UAA2081 to implement a bilevel drive at voltages as high as 50V. You can implement this drive by using high- and low-voltage motor supplies or a voltage-doubling circuit on the output.

***Incorporating two H-bridge drivers,** output-current regulators, and D/A converters, SGS-Thomson Microelectronics' L6217 and L6217A stepper-motor controllers allow you to microstep a 2-phase bipolar stepper motor. The plastic leaded chip carrier's special leadframe allows the devices to dissipate 2W.*

The UAB4718 and its extended-temperature-range version, the UAF4718, drive both windings of a 2-phase bipolar stepper motor with switch-mode current control of the phase currents. On a 10°C/W heat sink, the parts can handle continuous output currents as high as 1.5A with one motor phase on, or 0.9A with two motor phases on (the equivalent figures with no heat sinking are 0.7 and 0.4A) from a motor-supply voltage as high as 55V.

The 2081 and 4718 drivers feature an input decoder that allows you to step them through a full- or half-step sequence by applying a simple binary code to their control inputs. The decoder in these devices simplifies microcontroller firmware; for the 4718 parts, the decoder allows you to create a simple stepper-motor interface, with step and direction inputs, by adding only a standard binary up/down counter.

With its recently introduced 1A/45V bipolar stepper-motor driver, the UCN5871, Sprague continues its policy of placing both a counter and a decoder on chip to provide sequencing for a number of different stepping modes. Dedicated pins on the IC allow you to program the device so that it internally generates full-step, 1-phase-on (wave drive); full-step, 2-phase-on; or half-step sequences. Having programmed a particular mode, you can control the rotation of the motor simply by providing the device with step and direction inputs. Sprague hasn't entirely switched its attention to bipolar stepper motors. The company has also recently introduced the UCN5804B, a 1.25A/35V driver for unipolar stepper motors that provides control facilities similar to those of the UCN5871, but doesn't provide the output-current regulation.

Microsteps raise performance

Each stepper-motor driver listed in **Table 1** that has an on-chip comparator and control logic for switch-mode current control (with the exception of Signetics' TEA1012) provides an analog input that allows you to vary the winding current continuously. By driving this input, either from analog circuitry or from a D/A converter, you can microstep the motor. Microstepping involves balancing the two phase currents in the stepper motor so that the rotor assumes any desired angular position between the adjacent stator poles. The vector sum of the magnetic fields provided by each phase winding defines the angular position along which the rotor will align itself.

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Microstepping can improve system performance in a number of applications. For example, you can use it to improve the positional resolution of the stepper motor. Theoretically, you can divide each fundamental step interval of the motor by the number of discrete levels to which you can set the current in the motor windings. In practice, however, the achievable increase in positional resolution is limited by mechanical friction in the motor load and imperfections in the motor's magnetic circuits.

For example, in an open-loop position-control system, it would be difficult to microstep a 7.2° stepper motor by 1.8° with the same precision that you could obtain by full-stepping a 1.8° stepper motor. Because the 1.8° stepper motor's static-torque vs angular-displacement characteristic has a gradient around four times steeper than that of the 7.2° stepper motor, frictional or static load torque will result in a much smaller positional error for the 1.8° motor. If you use the 7.2° stepper motor, nonlinearity in the magnetic circuit when the rotor is between stator poles leads to additional positional errors.

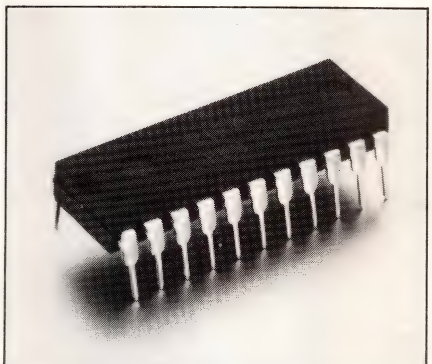
However, when you're implementing a closed-loop system, using an optical encoder to feed back the actual load position, a microstepped motor provides a convenient all-digital control system. In practice, 6- or 7-bit D/A converters provide sufficient phase-current resolution for most applications.

Eliminating resonance effects

Another advantage of microstepping is that it allows you to smooth the torque developed by the motor as it rotates. Stepper motors operating in a full- or half-step mode can misstep when their step frequency coincides with the frequency of mechanical resonances in the motor and its load; the problem typically manifests itself at speeds below 1 rps. Microstepping also eliminates the pulsed torque generated by full- or half-stepped motors, which can cause undue wear on reduction gearboxes or drive belts.

By using a D/A converter to synthesize a sinusoidal current waveform in one of the motor's phase windings, and using a cosinusoidal waveform in its second phase winding, you can create a smoothly rotating magnetic field for the rotor to follow. Because the microstep frequency of this field is well above mechanical resonances in the system, you can eliminate resonance problems. The frequency of the current waveforms determines the rotational speed of the motor, and by ramping the frequency up or down you can smoothly accelerate or decelerate the motor.

Three of the manufacturers listed in **Table 1** produce driver ICs specifically targeted for microstepping applications. SGS-Thomson Microelectronics' L6217 and L6217A both incorporate H-bridge driver stages, switch-mode current-control circuitry, and D/A converters for both windings of a 2-phase bipolar stepper motor. The L6217 has 6-bit D/A converters; the L6217A has 7-bit converters. Both devices interface directly to an 8-bit μP bus and are packaged in a 44-pin plastic leaded chip carrier that dissipates 2W. However, because of the devices' high-density bipolar technology, the devices' output stages operate only with motor supplies as high as 16V, and the package's power dissipation limits the continuous output current to 0.4A.



The PBM3960, together with the PBL3771, (both from Rifa) allows you to microstep a 2-phase bipolar stepper motor. The PBL3771 has 0.6A/40V continuous drive capability; the PBM3960 provides two 7-bit D/A converters and determines when the H-bridge output stage must be switched into a fast-current-decay mode.

In the second quarter of 1988, Mietec plans to introduce the MTC6018, a 0.8A H-bridge driver with an on-chip, switch-mode current regulator and a 6-bit D/A converter. It will operate with motor-supply voltages as high as 40V and come in a 20-pin DIP. To microstep a 2-phase bipolar stepper motor, however, you'll need two of the devices.

Rifa provides a 2-chip solution to microstepping with its PBL3771 driver IC and PBM3960 controller IC. Together, the two chips provide independent control of the winding current in both phases of a 2-phase bipolar stepper motor via an 8-bit μP bus. The PBM3960, in addition to providing two 7-bit D/A converters to microstep the motor, takes care of current-recirculation problems in the H-bridge output transistors. It automatically generates a fast-current-decay control signal that turns off all four H-bridge transistors in the PBL3771 driver when you need to reduce the winding current. The fast-current-decay mode is activated when the new D/A converter value is lower than the previous value. Two additional 3-bit registers allow you to define the three most significant bits of a threshold value for each winding, above which the fast-current-decay mode will be inhibited. By partitioning the system between a driver and a controller IC, Rifa provides a continuous drive capability of 0.6A per winding at motor-supply voltages as high as 40V, while implementing relatively complex control logic.

μCs simplify firmware

Although many stepper-motor applications require a microcontroller or μP for motion control, you don't necessarily have to get involved in writing machine-code firmware. Both Advanced Micro Systems Inc and Cybernetic Micro Systems Inc

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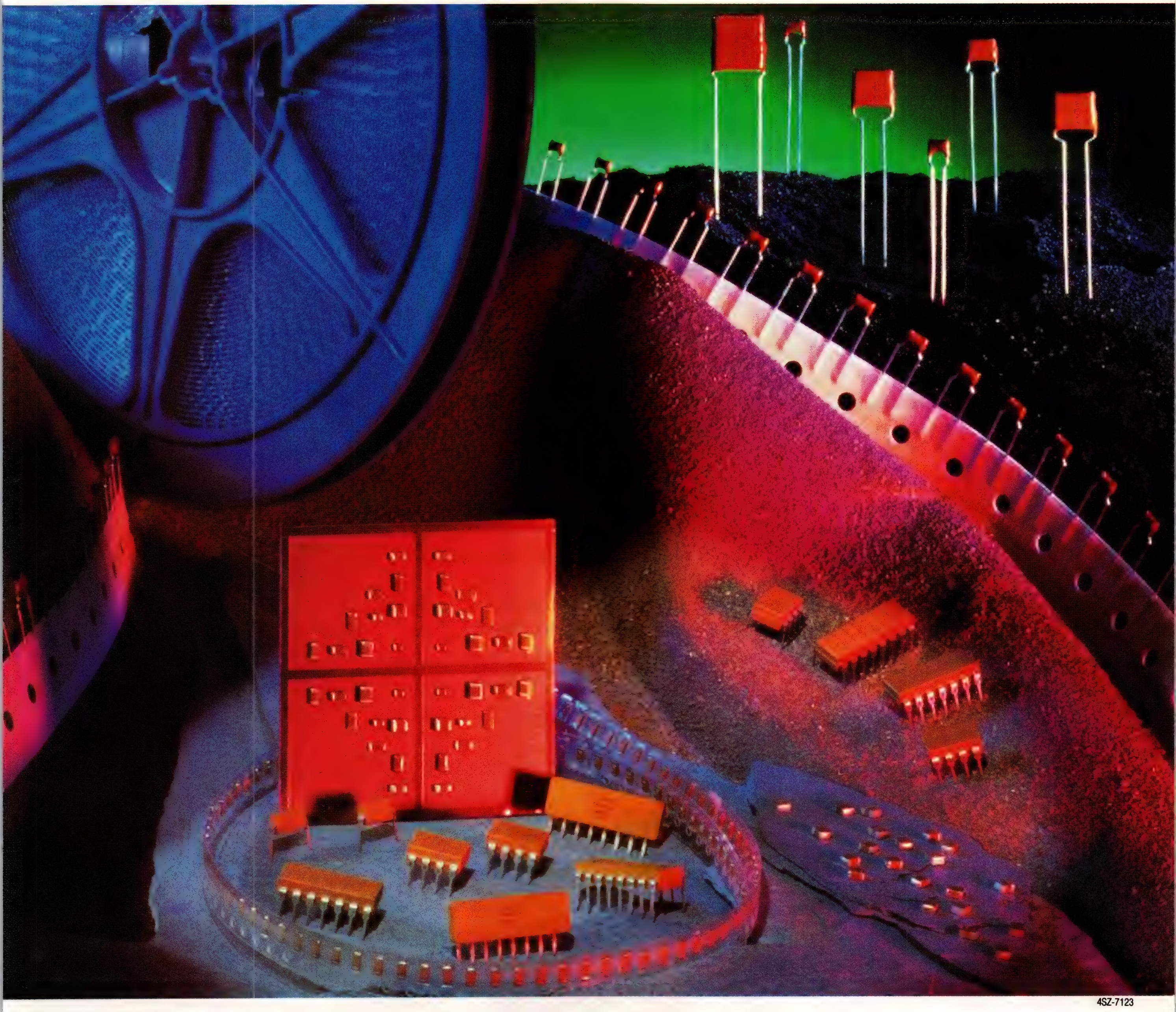

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produce dedicated microcontrollers that you can use to control a motor with high-level commands. The latest microcontrollers from Advanced Micro Systems are the SMC-23 and SMC-23C, and Cybernetic Micro Systems has just released the CY545, an addition to its CY family of stepper-motor controllers.

Both these devices accept ASCII-encoded commands via a parallel or a serial interface and allow you to perform a range of parameterized motor movements. For example, the $50 (1000) SMC-23 and SMC-23C allow you to specify initial and final velocities by using step rates as high as 18k steps/sec, and to conditionally execute motor movements, depending on the states of limit switches or other logic inputs. The SMC-23 generates four phase outputs suitable for driving power-output stages for unipolar or bipolar motors, as well as clock and direction outputs. It internally generates full-step, 2-phase-on and half-step phase sequences, but you can implement wave drive by defining this phase sequence in external memory. The SMC-23C is designed for power drivers that require step and direction inputs, but includes directionally sensitive encoder feedback inputs so that you can implement a closed-loop system.

Providing a repertoire of more than 30 commands, *Advanced Micro Systems' SMC23 is a dedicated microcontroller that allows you to perform complex stepper-motor moves with little or no host-processor intervention.*

The CY545, which sells for under $20 (1000), is also designed for drivers that require step and direction inputs. Although it provides high-level-command control facilities similar to those of other stepper-motor controllers in the CY Series, it differs in that you can also operate it as a stand-alone controller without a host processor. To support such use, the controller has limit-switch and manual jog inputs, and it can interrogate thumbwheel switches to determine parameter values. **EDN**

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1. Teja, Ed, "Sophisticated controller ICs adapt motors to robotics and computer-peripheral applications," *EDN*, October 17, 1985, pg 49.

2. Pryce, Dave, "Motor-control ICs extend performance of stepper and brushless dc motors," *EDN*, November 26, 1987, pg 61.

Article Interest Quotient
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For more information . . .

For more information on the stepper-motor driver/controller ICs discussed in this article, circle the appropriate numbers on the Information Retrieval Service card or contact the following manufacturers directly.

Advanced Micro Systems Inc
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(603) 882-1447
Circle No 719

Cherry Semiconductor Corp
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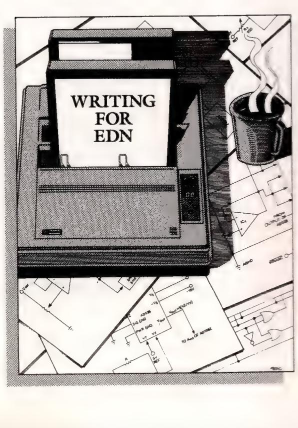

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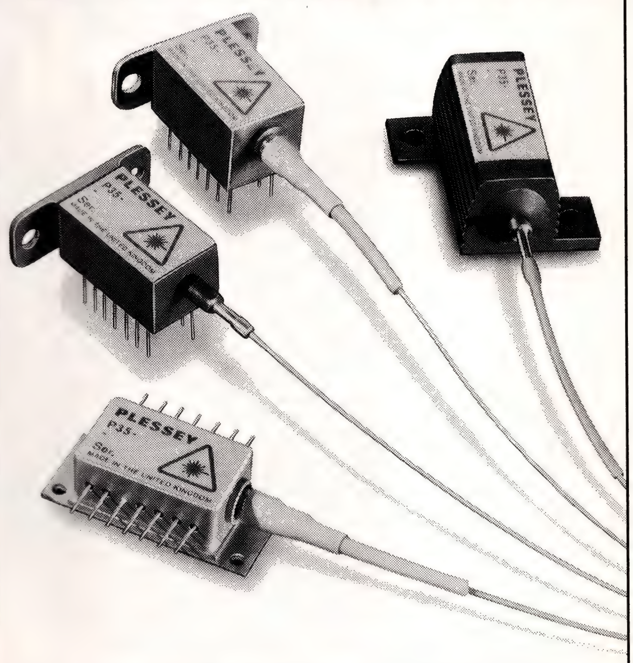

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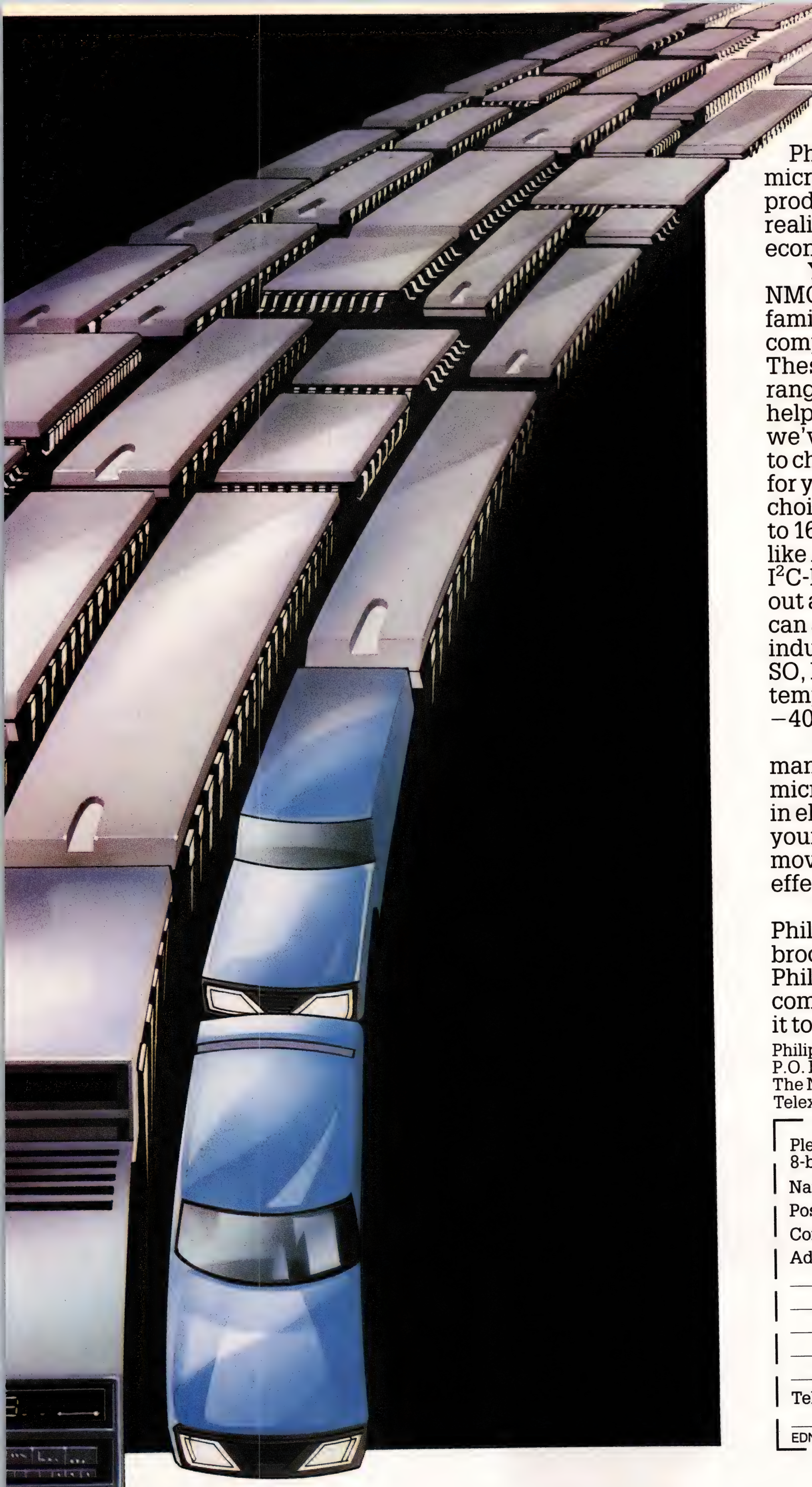

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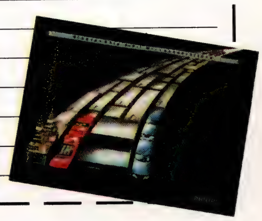

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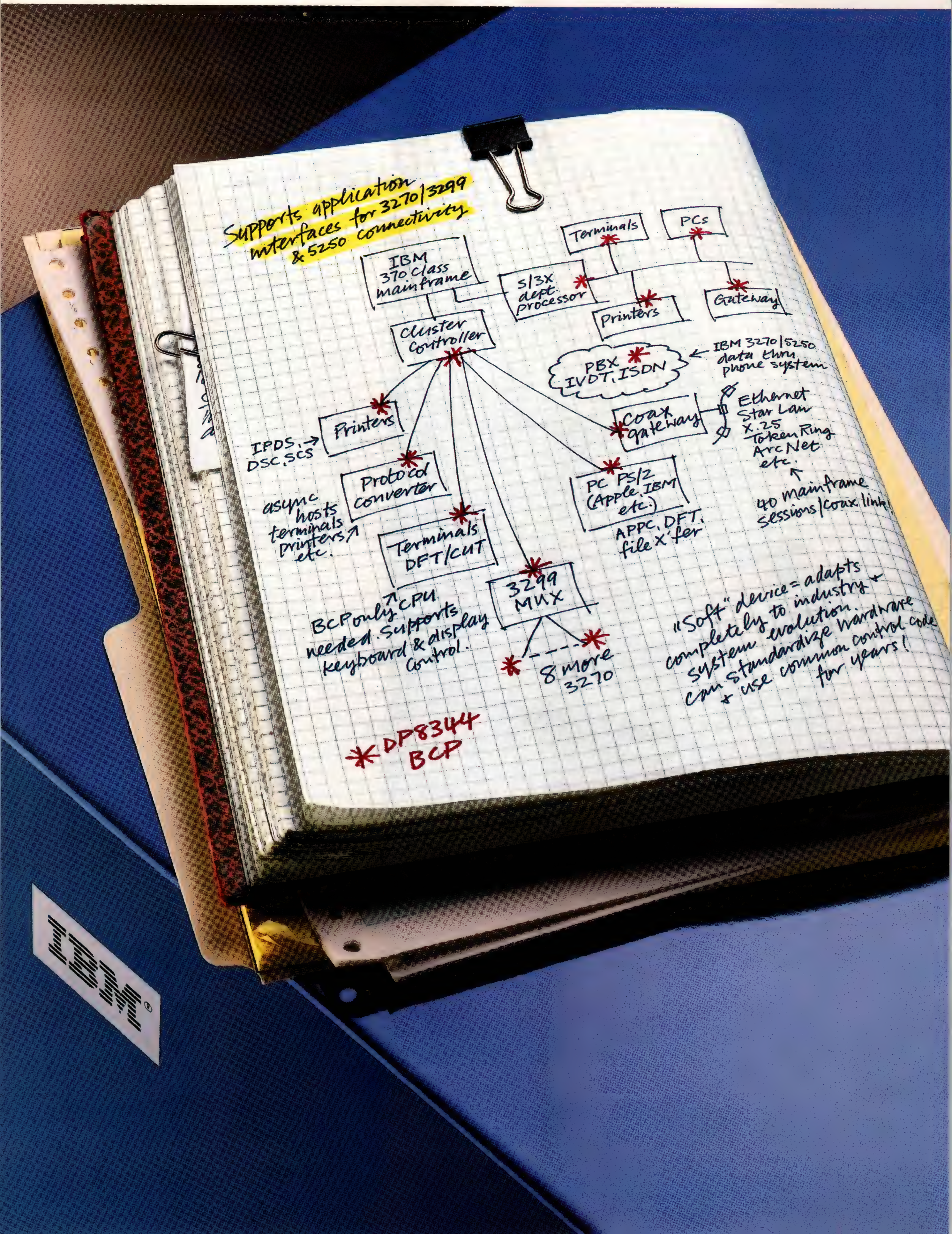

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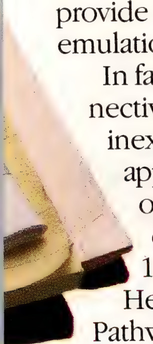

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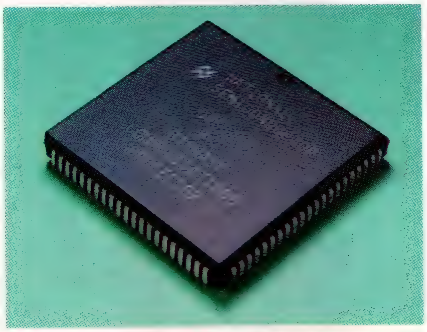

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The BCP features a software-configurable transceiver that supports not only IBM 3270, 3299 and 5250 protocols but also general eight-bit protocols.

A simple line interface connects the BCP to the communications line. The receiver includes an on-chip analog comparator and provides a TTL-level input for added flexibility.

WE'LL GIVE YOU ALL THE SUPPORT YOU NEED

The DP8344 is backed by a development package that includes a demo/evaluation board with a monitor/debugger program, in-system emulation features, and demonstration software for complete 3270 terminal emulation on an IBM PC.

On the system level, we offer both 3270 and 5250 controller emulators and analysis tools.

Application support is available through a worldwide network of technical support centers.

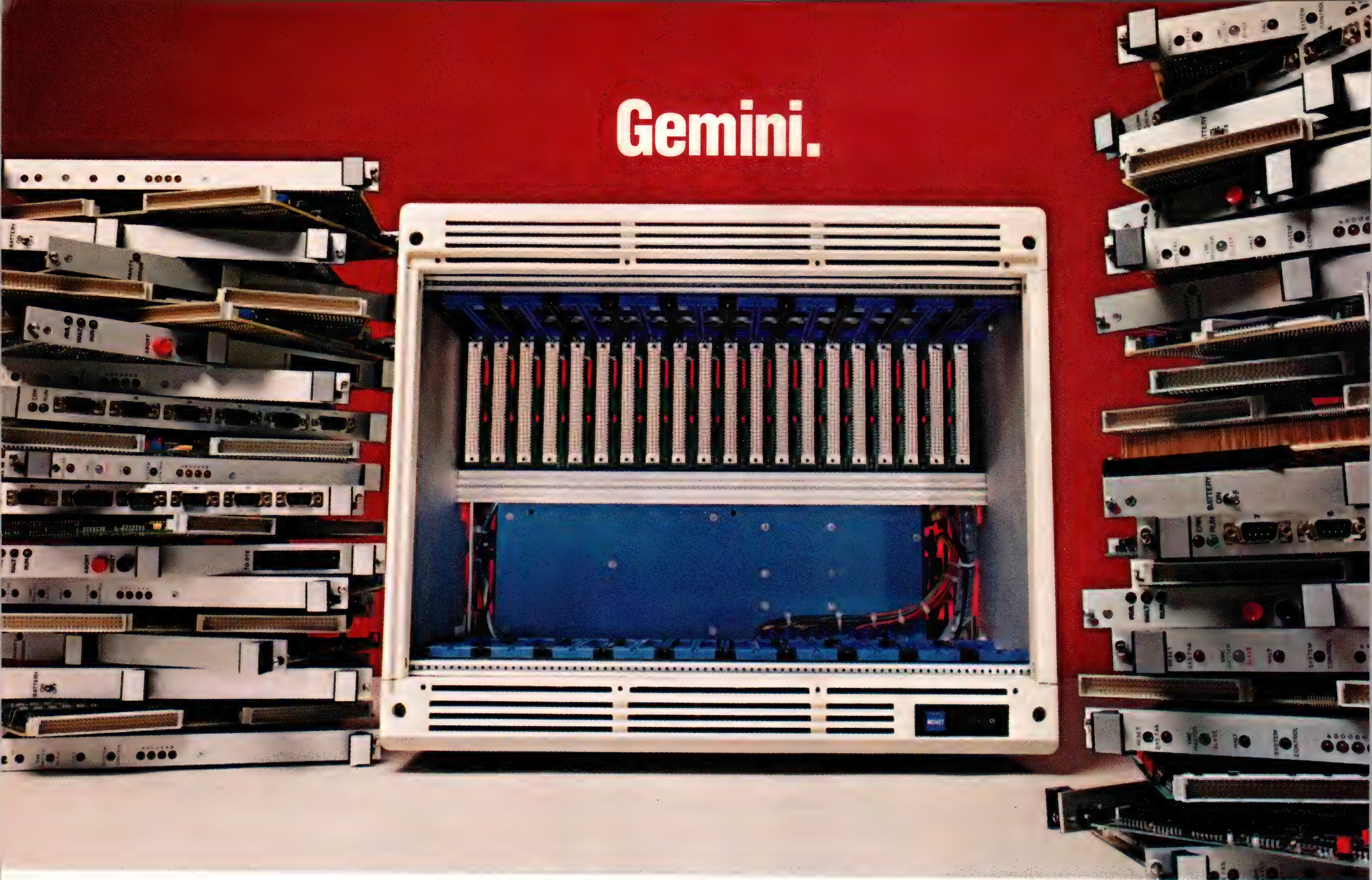
For more information on the DP8344 BCP— the easy, inexpensive way for you to provide IBM connectivity — please contact your National Sales Engineer.

Or write National Semiconductor, MS 23/200, P. O. Box 58090, Santa Clara, CA 95052-8090.

National Semiconductor

Advanced Peripherals

CIRCLE NO 112



A New VME Enclosure with Benefits That Really Stack Up:

40 Slot Capacity. Big systems in less space. In its maximum configuration, Gemini has *two* 20-slot VME card cages and two power supplies—two complete 20-slot VME systems in a single package only 14″ high, 26″ deep. One takes cards from the front, the other from the rear.

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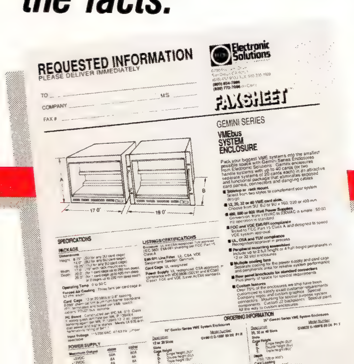
We'll FAX you the facts.



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CIRCLE NO 113

Monolithic, self-calibrating ADC includes sample-and-hold amplifier

The monolithic ML2230 combines a 12-bit (plus sign) A/D converter and a sample-and-hold (S/H) amplifier with self-calibration and interface circuitry on a 3-μm CMOS chip. The device, which is compatible with 8-bit data buses, comes in a 24-pin DIP and delivers its 13-bit output in two consecutive bytes. The A/D converter's successive-approximation architecture can execute 30-μsec conversions, yet doesn't employ the usual resistor ladder or capacitor array.

The conversion algorithm has an S/H and gain-of-2 amplifier **(Fig 1)** in place of the D/A converter used in most successive-approximation schemes. The ML2230 first multiplies V_{IN} by 2 and compares the result with V_{REF}. If the result is greater than V_{REF}, the MSB becomes 1 and the S/H amplifier stores the difference $(2V_{IN}-V_{REF})$. If the result is less than V_{REF}, the MSB becomes 0 and the S/H amplifier stores $2V_{IN}$. The circuit then multiplies the S/H voltage by 2, compares the result with V_{REF}, and proceeds in this manner to determine the remaining 12 bits.

The ML2230 and its predecessor, the ML2200, are the first commercial, monolithic A/D converters to use this successive-approximation algorithm, although the algorithm was originally developed in 1950. Because they don't include internal D/A converters, these products require less circuit area and much less component trimming than do conventional successive-approximation converters. Indeed, the ML2230's self-calibration circuitry eliminates the need for trimming altogether.

An external command initiates the self-calibration, which requires 8260 cycles of the internal clock (about 2 msec at the maximum rate

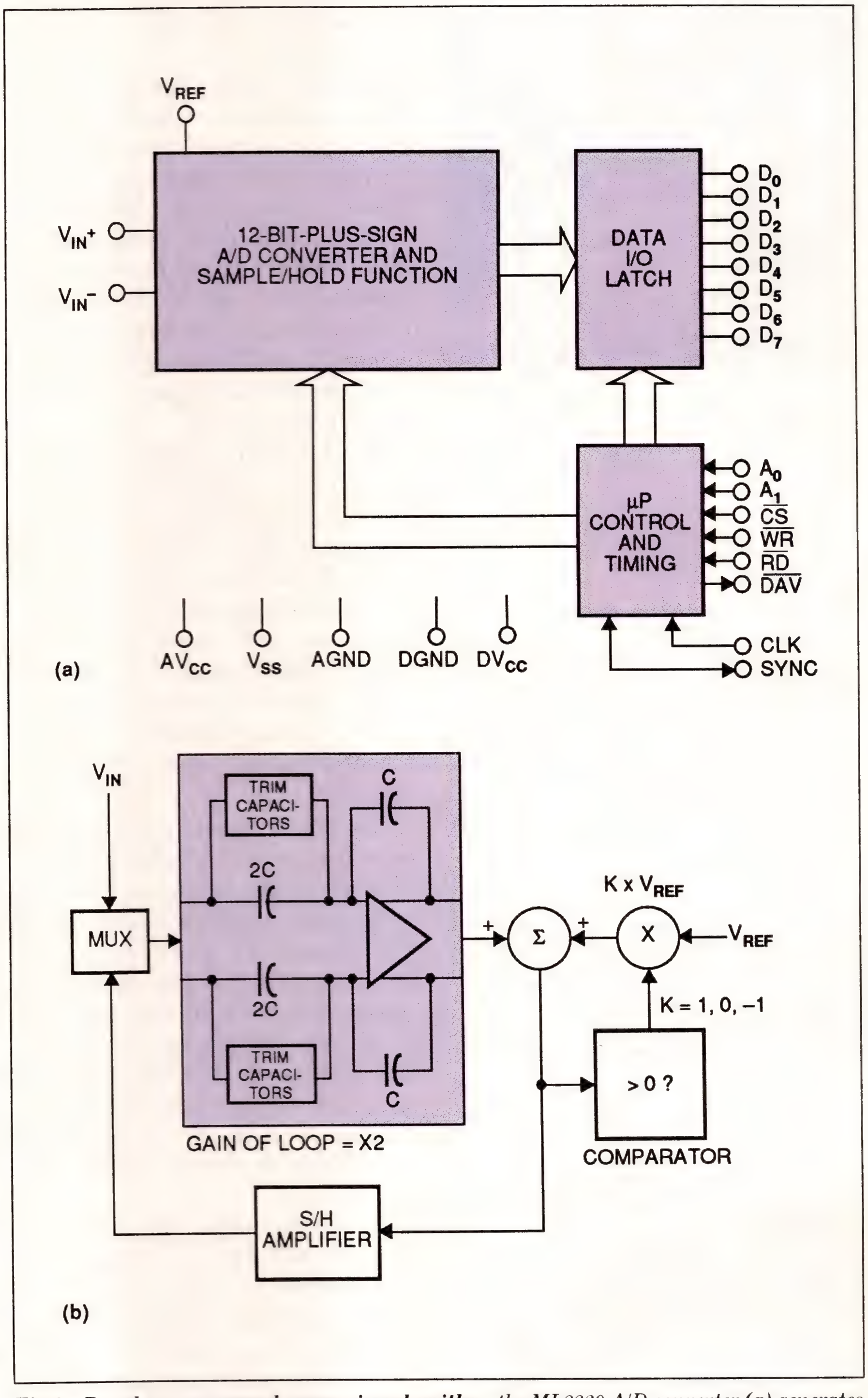

Fig 1—Based on an unusual conversion algorithm, *the ML2230 A/D converter* ***(a)*** *generates a 13-bit output (12 bits plus sign) in two consecutive bytes. The device uses a gain-of-2 amplifier and a sample-and-hold amplifier* ***(b)*** *instead of the D/A converter found in most other successive-approximation converters. The part's minimum conversion time is 30 μsec.*

of 8 MHz). First, autozero circuits on the sampling amplifier and the 2× amplifier null the loop offsets as they do before every conversion. The loop then adjusts itself with 13-bit accuracy for a gain of 2.

To make this adjustment, the ratiometric converter internally connects V_{REF} as V_{IN}, initiates a conversion, notes the output, and adjusts the gain by adding or subtracting binary-weighted trim capacitors in the positions shown in **Fig 1**. Under these conditions, a properly calibrated converter is on the threshold of producing all ones, which allows the LSB-switching threshold to serve as the converter's calibration-complete signal. The calibration also compensates for errors in the S/H amplifier.

The ML2230's differential inputs can withstand an overvoltage of 7V beyond either of the ±5V supplies without latching. What's more, the chip will not latch up if it's exposed to input voltages when the supply voltages are off. The input common-mode range includes the supply rails, and the device requires a 2.500V external reference. The differential-input signal range is $\pm V_{REF}$.

The analog inputs present a high impedance except when the converter is sampling. Then, the input signal charges a pair of balanced 9-pF input capacitors. When the converter is operating in the continuous-conversion mode at the maximum clock rate, for example, the charging occupies 2 μsec of every 27.5 μsec—allowing source-impedance values as high as 2 kΩ while converting dc inputs with 13-bit accuracy.

By maintaining a differential signal path from the input, through the S/H amplifier, and into the A/D converter, the chip provides 80-dB PSR (dc, typ) and an 80-dB (min) CMR. The available linearity grades of ±½ LSB (ML2230B) and ±1 LSB (ML2230C) apply over the specified ranges of temperature and supply voltage.

The converter's digital interface supports high-speed data transfers by polling, interrupt, and DMA techniques. For an 8-bit bus, the DMA option allows high- and low-byte reads from the same I/O address, and you can select the byte order to comply with Motorola or Intel bus conventions. Double-buffered data registers allow the system to read data while the next conversion is in progress. You can initiate conversions by reading or writing to a data register, applying an external trigger pulse, or relying on an internal trigger (when the converter is in continuous-conversion mode).

Finally, built-in diagnostics let you test the ML2230's analog and digital circuitry. You can test the digital paths with a loopback routine that routes data from a write register through the calibration register and converter, and back to a read register. (You can also verify a calibration by reading the calibration data.) The device's analog diagnostic facilities include measurement of bipolar offset, full-scale error, and common-mode rejection.

For direct connection to a 16-bit data bus, the ML2233 version of the device offers 13 output lines. The ML2233 is particularly well suited to modem applications, which require 13-bit resolution and a conversion time of 40 μsec or less. Both parts are available in the same linearity grades, and both come in 28-pin plastic or ceramic DIPs or 28-pin PLCCs. An ML2230 or ML2233 with a linearity error of ±1 LSB at 13 bits costs $15.95 (100).

—Tarlton Fleming

Micro Linear Corp, 2092 Concourse Dr, San Jose, CA 95131. Phone (408) 262-5200. TLX 275906.

Circle No 739

Z I L O G

Z280

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Speed	10-25 MHz	8-12.5 MHz	10 MHz
Memory Support	16 Mb Physical Paged	1 Mb Physical Segmented	16 Mb Physical 8 or 128 Segments
16-bit Registers	12 General	8 General	15 Dedicated
Instruction Pre-fetch	256-Byte Assoc. Cache; Burst Mode	6-Byte Queue	None
Multiprocessor Support	Local or Global	Local only	Local only
Wait Logic	Programmable	Programmable	Hardwire
DMA	4 Channels, 6.6 Mb/s @ 10 MHz	2 Channels 2 Mb/s @ 8 MHz	2 Channels, 3.2 Mb/s @ 10 MHz
Counter/Timers	3 16-bit	3 16-bit	2 16-bit
Serial I/O	1 Full-Duplex UART	None	1 Full-Duplex UART
DRAM Controller	10-bit Refresh	None	None
Price (100)	$33	$43	$50

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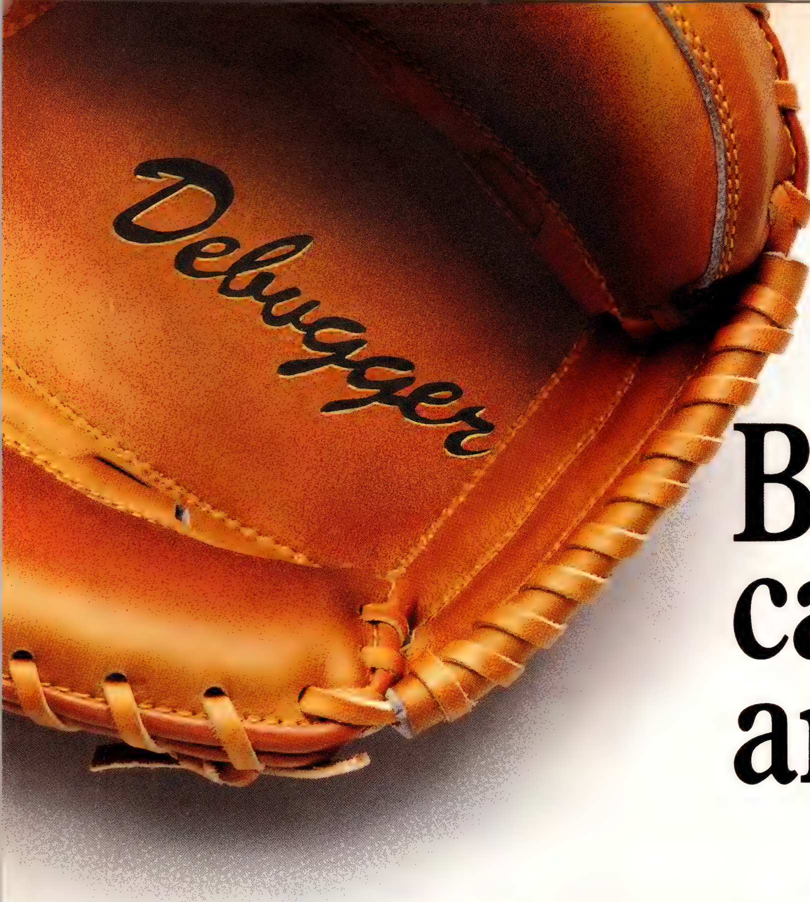
CIRCLE NO 114



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CIRCLE NO 115

Monolithic gallium arsenide ICs support fiber-optic applications

The ALD30010, a 10-kHz to 3.0-GHz laser-diode driver, is a member of the latest generation of gallium arsenide ICs, which promise to free fiber-optic systems from some of their traditional limitations. For example, despite the virtually unlimited bandwidth of the fiber itself, present fiber-optic systems encounter data-rate limits of about 1.7G bps because of the restrictions imposed by most ICs, as well as by packaging and connector technologies. ICs such as the ALD30010 lead the trend toward extending the data-rate limits for future long-haul telecommunications systems and wide-bandwidth video links.

The ALD30010 is the latest product of the vendor's effort to provide a GaAs chip set for the transmitter and receiver sections of high-data-rate fiber-optic systems. The ALD30010 contains four FET devices and a 180° phase splitter (**Fig 1**). The phase splitter provides high reverse isolation for good input matching, and it has sufficient gain to provide input sensitivity of 0.6V p-p (0 dBm) for a single-ended input signal.

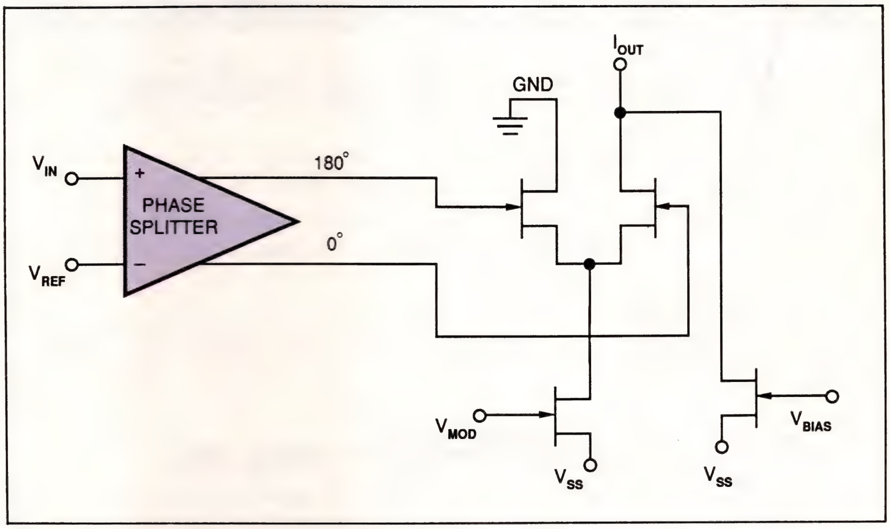

Fig 1—The ALD30010 laser-diode driver includes a phase splitter and four FET devices. *The phase splitter provides reverse isolation and has sufficient gain to provide input sensitivity of 0.6V p-p. The modulation current range is adjustable from 0 to 30 mA.*

The ALD30010 can operate to 4.5 GHz as an analog current driver and to 5G bps in digital fiber-optic systems. The chip has a standing-wave ratio of less than 2:1 over its full frequency range. By means of a voltage-control function, you can adjust the offset current from 0 to 70 mA and the modulation range from 0 to 30 mA. Besides employing the chip as a laser-diode driver in fiber-optic applications, you can use the ALD30010 as a wideband buffer amplifier or as an analog current driver.

You can use the ALD30010 in ap-

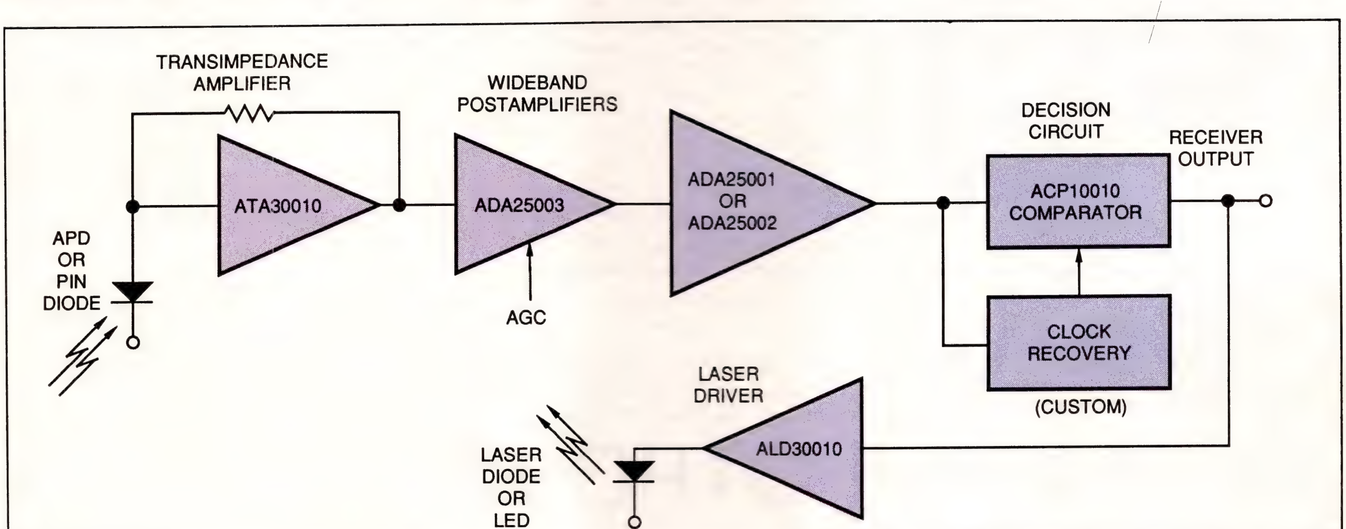

Fig 2—This block diagram of a typical fiber-optic transceiver *shows one application for the ALD30010 laser-diode driver and other GaAs devices from the vendor.*

plications such as the fiber-optic transceiver shown in **Fig 2.** The circuit also uses other GaAs chips from the vendor. For example, the ATA30010 transimpedance amplifier amplifies the light pulses from a pin diode or APD (avalanche photodiode). An ADA25001 or ADA25002 and an ADA25003 act as wideband postamplifiers, controlling the signal level to the ACP10010 comparator (the decision circuit), which provides the receiver output. (The ADA25003, which is currently in the prototype stage, is similar to the 25001 and 25002 except that it also has AGC capability.) The output of the ACP10010 supplies the input to the ALD30010 laser-diode driver in NRZ (nonreturn-to-zero) form.

The ALD30010 laser driver costs $43.50 in chip form and $65 (1000) in an 8-pin flat pack. Likewise, the ADA25001 amplifier costs $36 and $54, the ADA25002 amplifier is $19 and $28.50, and the ACP10010 comparator sells for $12.95 and $19.50. The ATA30010 transimpedance amplifier costs $43.50 in chip form. All the ICs except the ADA25003 prototype are available now. An evaluation kit for the laser driver costs $995; it includes a test fixture and five ALD30010 devices.

—Dave Pryce

Anadigics Inc, 35 Technology Dr, Warren, NJ 07060. Phone (201) 668-5000. TWX 510-600-5741. FAX (201) 668-5068.

Circle No 740

Pocket-size smart-card terminal offers voice and data communications

You no longer need a PC to program the vendor's 8-bit-μP-based Memocard smart cards: You can now program them simply by plugging them into the pocket-size Multiportable terminal. The Multiportable unit functions as a computer with built-in word-processing and arithmetic functions, a numeric keypad, and a clock. You can plug an optional modem into the terminal for remote data communication.

You can load application programs into the Multiportable terminal from the credit-card-size Memocard; the terminal runs the programs in much the same way that a desktop computer executes software from a floppy disk. The terminal reads program data from a Memocard or an external port and then executes the program from RAM. You can also use the terminal to store and retrieve data on a Memocard.

The Multiportable has a 2-line, 16-character LCD and a 66-character qwerty keyboard. The 6½×3¾×1¼-in. terminal weighs 12 oz and contains a proprietary 8-bit μP, 32k bytes of RAM, 32k bytes of ROM, a Memocard port, an RS-232C port, a modem port, and an expansion port. A snap-on cover protects the keyboard, display, and connectors. The terminal operates from a rechargeable 6V battery or from ac power.

Because both the Memocard and the Multiportable terminal are μP-controlled, you can restrict access to the functions of either device via a security/encryption scheme that can include multiple levels of passwords and encryption algorithms. Furthermore, any attempt to remove the μP from a Memocard results in the destruction of the μP.

The unit's standard communication interface includes two RJ11 telephone ports, dual-tone multifrequency (DTMF) transmission, pulse-width timing for tone detection, and a speaker. These features let you use the Multiportable terminal as an autodialer, a speakerphone, and a call timer. The terminal also lets you store names, addresses, and phone numbers in an electronic directory. An optional 1200-bps modem provides access to remote computers and electronic databases.

Suitable for use in security-oriented applications such as field-service control, database management, computer-network control, and process control, a single Multiportable terminal with a modem sells for $650. The price drops to $455 when you order at least 25. A single 2k-byte Memocard sells for $79; an 8k-byte Memocard costs $139.—***J D Mosley***

Multimil Inc, 670 International Parkway, Suite 190, Richardson, TX 75081. Phone (214) 644-7724. TLX 286258.

Circle No 741

Weighing 12 oz and measuring 6½×3¾×1¼ in., *the Multiportable terminal lets you read, write, and program a Memocard smart card that contains an 8-bit μP and 2k or 8k bytes of EEPROM. An optional modem adds voice- and data-communication capabilities to the terminal's standard word-processing and calculating functions.*

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CIRCLE NO 117

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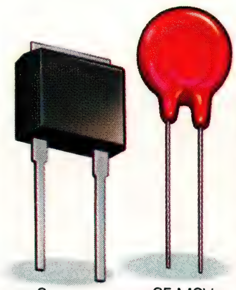

Now, whether you're designing small consumer products, industrial controls, high-rel military and aerospace systems, or anything in between, we have a surge protection solution for you. Because if one of our GE-MOV varistors isn't exactly right for the job, then one of our Surgectors probably will be.

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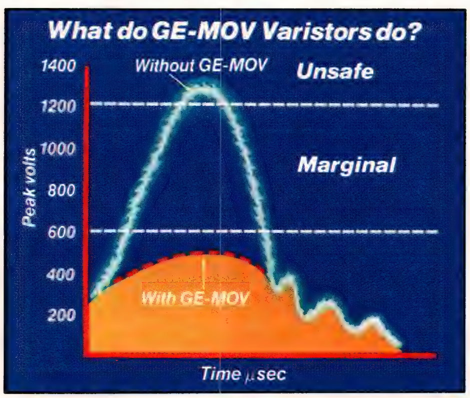

They're available in a variety of packages, including axial leaded, radial leaded, leadless surface mount, high-energy modules and connector-pin configurations. And they're all available for fast delivery.

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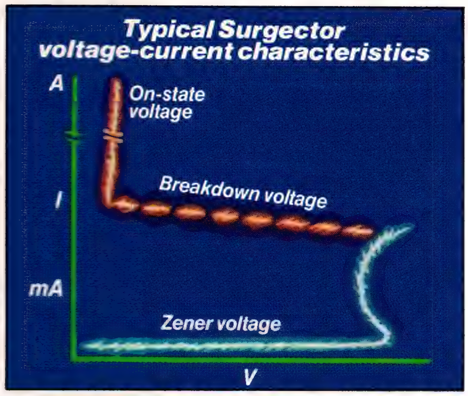
Surgector devices respond rapidly and handle a lot of energy. So they're ideal for protecting sensitive or expensive components from lightning strikes, load changes, switching transients, commutation spikes, electro-static discharge and line crosses.

How they work.

Surgector devices combine a zener diode and an SCR into one reliable, cost-effective device.



At low voltages, the Surgector is "off," representing high forward impedance (only 50nA leakage current). The instant clamping voltage is exceeded, the Surgector turns "on" and the zener immediately starts conducting. Within nanoseconds, the SCR turns on to handle heavy currents. Destructive surges are shunted to ground.

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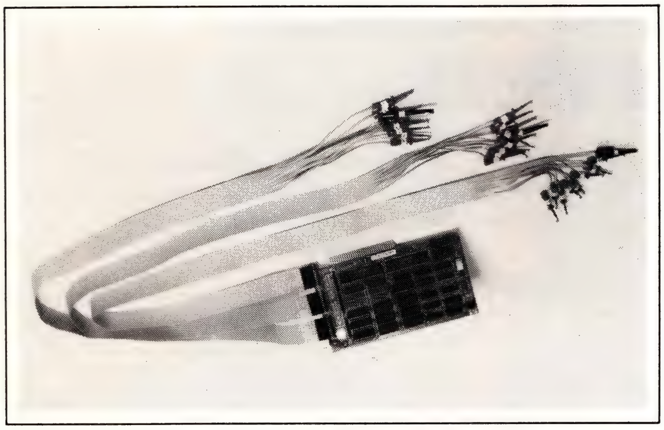
READERS' CHOICE

Of all the new products covered in EDN's **November 12, 1987,** issue, the ones reprinted here generated the most reader requests for additional information. If you missed them the first time, find out what makes them special: Just circle the appropriate numbers on the Information Retrieval Service card, or refer to the indicated pages in our **November 12, 1987,** issue.

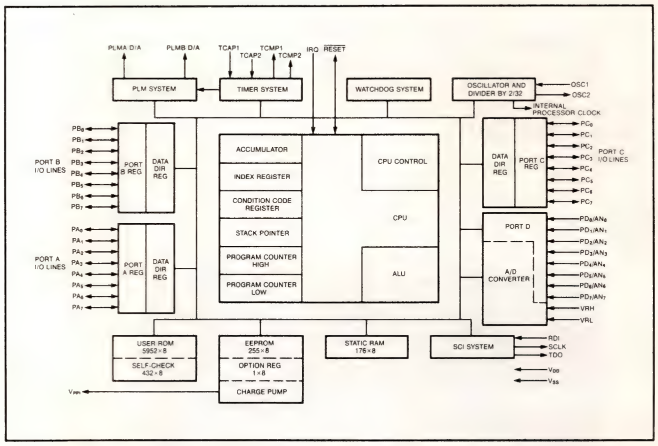


◀ LOGIC ANALYZER

The PC-29 logic analyzer is a half-sized I/O card for the IBM PC, PC/XT, PC/AT, and 100%-compatible computers equipped with CGA, EGA, or Hercules display adapters and at least 256k bytes of RAM (pg 364).
El Toro Systems
Circle No 602

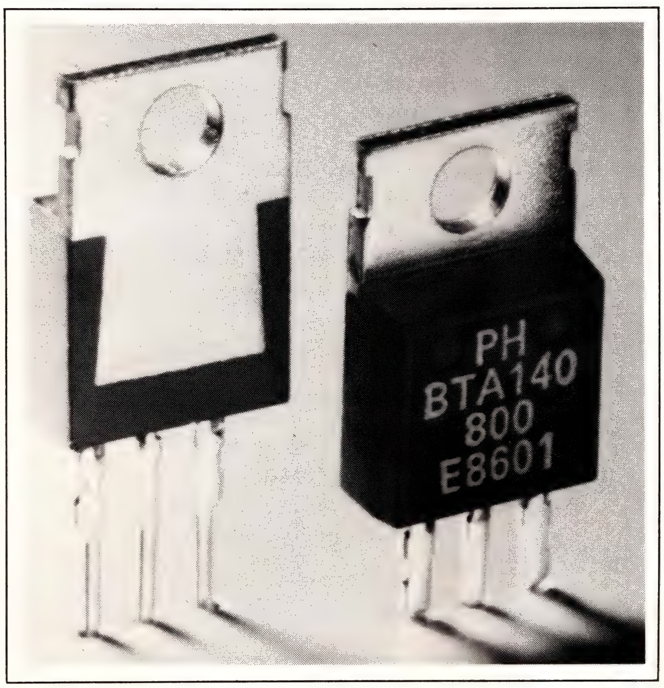
MULTITASKING WITH C

Multi-C is a library of C-language functions that you can link to a program to convert the program into a number of time-independent tasks (pg 379).
Cytek Inc
Circle No 601



▲ HIGH-SPEED CMOS μC

The MC68HC05B6 1-chip μC is an upgraded version of the MC68HC05C4; it includes an 8-channel A/D converter, 256 bytes of EEPROM, and bidirectional I/O for synchronous and asynchronous communication (pg 98).
Motorola Inc
Circle No 603



▲ TRIACS

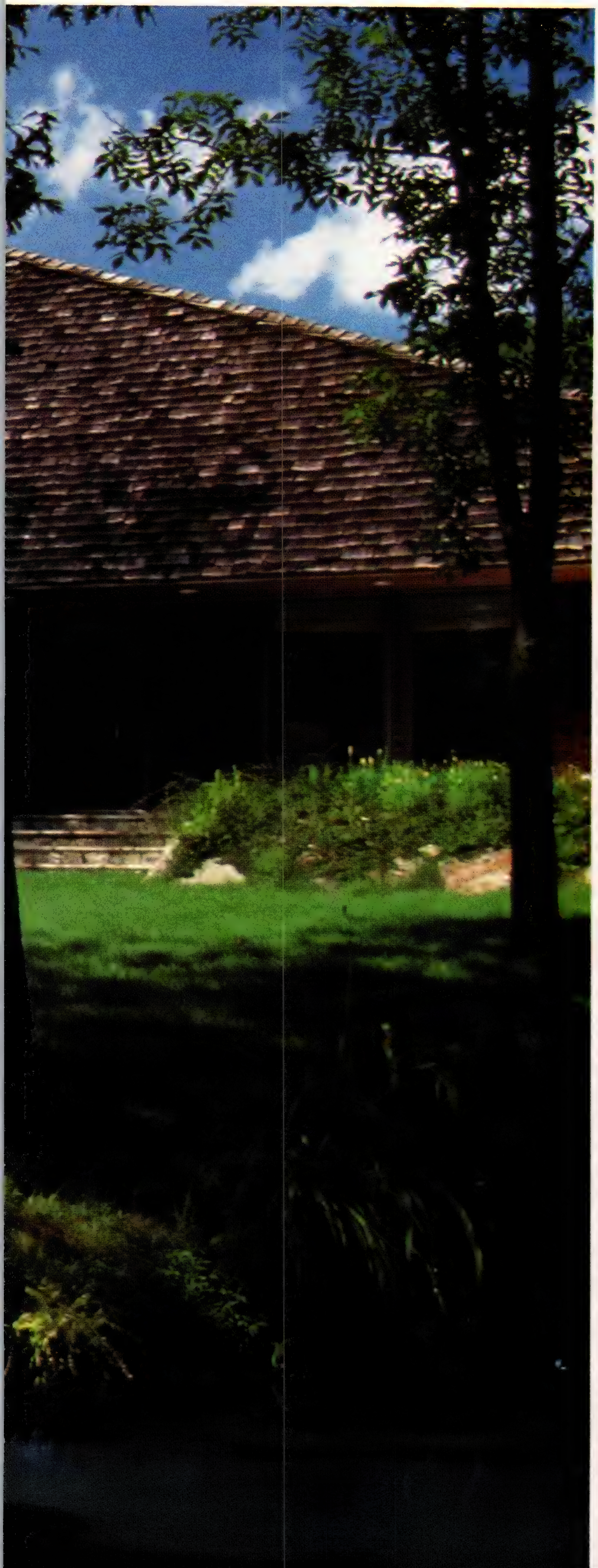
BTA 140 Series glass-passivated triacs have an on-state current-handling capability of 25A rms (pg 332).
Amperex Electronic Corp
Circle No 606

KEYBOARDS

The SF62000-Input conductive-rubber keyboards are suitable for harsh environments, yet feature tactile feedback similar to that of full-travel keyboards (pg 95).
Marconi Electronic Devices Ltd
Circle No 604
Marconi Electronic Devices Inc
Circle No 605

What do you need to build on a rough application concept?

onents of success.



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AT&T is in the components business to stay. We have formed a separate unit, AT&T Microelectronics, to bring our more than 100 years of electronic components experience to the marketplace. And, we have the capital, people, and technical savvy to meet our commitment to the future.

The component of innovation: AT&T Bell Labs.
Count on Bell Laboratories to help make your 'blue-sky' designs a reality. With everything from DSPs and optical data links, to custom designed products such as ASICs, multilayer boards, and power supplies. And throughout planning and manufacturing, count on AT&T to keep your product up to the minute with the latest Bell Labs advances.

The component of quality.
Through our Integrated Quality System, Bell Labs engineers work with our quality professionals to meet customer-defined criteria. At AT&T quality is our history—and our future.

The component of management involvement.
AT&T Microelectronics gives you total support, right up to its president, Bill Warwick. If our solutions aren't on the money, call him at 1 201 771-2900.

The component of quick response.
With 12 plants and an extensive network of design centers and sales offices worldwide, AT&T is ready to meet your volume demand for components. Ready with everything you need to get ideas off the ground and in the market—successfully.

To learn why AT&T is more than ever the right choice, just give us a call.

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AT&T Microelectronics Major Product Lines:

- ASICs
- Digital Signal Processors
- Communication ICs
- 32-bit Microprocessors and Peripherals
- Solid State Relays
- Multilayer Circuit Boards
- HICs
- Optical Data Links
- Fiber Optic Components
- Power Products
- Transformers and Inductors
- Wound Film Capacitors

AT&T
The right choice.

CIRCLE NO 126

LEADTIME INDEX

Percentage of respondents

ITEM	Off the shelf	1-5 weeks	6-10 weeks	11-20 weeks	21-30 weeks	Over 30 weeks	Average (weeks)	Last month's average (weeks)
TRANSFORMERS								
Toroidal	0	16	63	16	5	0	9.3	8.7
Pot-Core	7	7	65	14	7	0	9.4	10.0
Laminate (power)	0	35	38	23	4	0	8.7	7.7
CONNECTORS								
Military panel	0	15	38	39	8	0	11.5	11.2
Flat/Cable	12	42	29	13	4	0	6.6	5.4
Multi-pin circular	0	14	50	36	0	0	10.0	8.2
PC (2-piece)	5	21	63	11	0	0	7.3	5.8
RF/Coaxial	18	29	35	18	0	0	6.4	5.1
Socket	14	41	38	7	0	0	5.3	3.6
Terminal blocks	12	40	40	8	0	0	5.6	4.5
Edge card	6	33	56	5	0	0	6.3	6.4
D-Subminiature	13	29	50	8	0	0	6.2	4.5
Rack & panel	6	41	35	18	0	0	6.8	7.4
Power	6	41	29	24	0	0	7.2	7.4
PRINTED CIRCUIT BOARDS								
Single-sided	5	57	33	5	0	0	5.1	5.9
Double-sided	0	34	57	9	0	0	6.9	6.9
Multi-layer	0	9	86	5	0	0	7.9	7.7
Prototype	7	79	14	0	0	0	3.5	4.2
RESISTORS								
Carbon film	40	30	27	3	0	0	3.6	3.3
Carbon composition	38	31	28	3	0	0	3.1	5.0
Metal film	23	40	34	3	0	0	4.4	4.4
Metal oxide	19	44	31	6	0	0	4.8	4.9
Wirewound	6	26	55	13	0	0	7.2	5.8
Potentiometers	6	41	41	12	0	0	6.4	5.0
Networks	14	45	41	0	0	0	4.7	5.7
FUSES	32	42	21	5	0	0	3.8	3.8
SWITCHES								
Pushbutton	11	44	30	15	0	0	6.0	4.8
Rotary	0	48	35	13	4	0	7.3	5.3
Rocker	12	44	32	12	0	0	5.7	5.2
Thumbwheel	9	29	33	24	5	0	8.4	6.2
Snap action	14	36	43	7	0	0	5.6	5.0
Momentary	4	55	32	9	0	0	5.6	6.3
Dual in-line	0	43	50	7	0	0	6.4	6.2
WIRE AND CABLE								
Coaxial	36	36	28	0	0	0	3.3	3.7
Flat ribbon	21	46	33	0	0	0	4.0	3.7
Multiconductor	27	32	36	5	0	0	4.6	4.5
Hookup	35	42	23	0	0	0	3.1	3.5
Wire wrap	28	18	54	0	0	0	4.8	4.4
Power cords	26	44	19	11	0	0	4.5	4.9
POWER SUPPLIES								
Switcher	5	15	50	20	10	0	10.1	8.3
Linear	6	19	44	25	6	0	9.5	7.8
CIRCUIT BREAKERS	0	24	57	19	0	0	8.2	7.1
HEAT SINKS	10	35	45	10	0	0	6.2	5.0
RELAYS								
General purpose	8	33	42	17	0	0	6.9	5.6
PC board	0	33	38	29	0	0	8.5	6.9

ITEM	Off the shelf	1-5 weeks	6-10 weeks	11-20 weeks	21-30 weeks	Over 30 weeks	Average (weeks)	Last month's average (weeks)
RELAYS								
Dry reed	0	36	27	37	0	0	8.9	7.0
Mercury	0	30	40	30	0	0	8.8	8.8
Solid state	6	35	35	24	0	0	7.5	9.0
DISCRETE SEMICONDUCTORS								
Diode	17	31	25	22	5	0	7.8	5.1
Zener	12	29	24	29	6	0	8.8	5.5
Thyristor	10	16	32	42	0	0	9.5	7.9
Small signal transistor	4	38	29	21	8	0	8.8	5.7
MOSFET	0	50	23	23	4	0	8.0	9.0
Power, bipolar	0	40	40	20	0	0	7.5	8.0
INTEGRATED CIRCUITS, DIGITAL								
Advanced CMOS	5	24	33	38	0	0	9.3	7.3
CMOS	4	28	36	32	0	0	8.7	6.5
TTL	19	39	27	15	0	0	5.7	5.9
LS	18	39	25	18	0	0	5.9	5.2
INTEGRATED CIRCUITS, LINEAR								
Communication/Circuit	0	38	25	37	0	0	8.9	8.5
OP amplifier	11	26	37	26	0	0	7.8	7.1
Voltage regulator	7	45	27	21	0	0	6.8	5.8
MEMORY CIRCUITS								
RAM 16k	19	33	14	34	0	0	7.3	4.1
RAM 64k	13	30	26	31	0	0	7.7	6.5
RAM 256k	22	11	22	39	6	0	10.0	6.7
RAM 1M-bit	8	17	25	42	8	0	11.1	11.8
ROM/PROM	0	47	13	40	0	0	8.7	7.7
EPROM 64k	8	33	21	38	0	0	8.5	6.5
EPROM 256k	5	32	21	37	5	0	9.7	7.5
EPROM 1M-bit	0	14	22	50	14	0	13.5	10.5
EEPROM 16k	0	36	21	43	0	0	9.4	8.5
EEPROM 64k	7	27	20	46	0	0	9.6	8.5
DISPLAYS								
Panel meters	8	38	31	23	0	0	7.2	6.4
Fluorescent	0	10	30	50	10	0	13.0	9.4
Incandescent	12	38	0	50	0	0	8.9	6.9
LED	8	46	23	23	0	0	6.8	5.4
Liquid crystal	0	30	35	29	6	0	9.8	8.6
MICROPROCESSOR ICs								
8-bit	8	40	20	32	0	0	7.8	6.8
16-bit	10	33	9	48	0	0	9.1	7.0
32-bit	6	35	18	41	0	0	8.9	9.8
FUNCTION PACKAGES								
Amplifier	0	22	33	45	0	0	10.2	8.0
Converter, analog to digital	7	13	40	40	0	0	9.8	7.9
Converter, digital to analog	0	8	50	42	0	0	10.7	8.0
LINE FILTERS	7	26	47	20	0	0	7.6	7.3
CAPACITORS								
Ceramic monolithic	10	38	38	14	0	0	6.3	5.7
Ceramic disc	13	33	37	17	0	0	6.5	5.7
Film	15	27	35	19	4	0	7.5	5.9
Aluminum electrolytic	12	34	30	24	0	0	7.2	7.1
Tantalum	8	32	41	19	0	0	7.1	6.9
INDUCTORS	5	27	50	18	0	0	7.6	6.3

Source: *Electronics Purchasing* magazine's survey of buyers

You told us what you wanted in digitizing oscilloscopes,

and we took your advice...

...AGAIN.

Introducing HP's new high-perfo

You told us what would best meet your measurement needs.

So in '84 and '85 we brought you digitizing oscilloscopes with pioneering features like full programmability, 1 GHz repetitive bandwidth, color displays, automatic answers, single-shot pulse reconstruction, infinite persistence, and instant hardcopy output.

And now, we bring you the new HP 54111D/54112D/ 54120T series.

These high-performance digitizing oscilloscopes let you measure what you've never measured before, with superb accuracy and ease of use.

You'll find innovations such as 20 GHz bandwidth, 4-channel simultaneous 400 MSa/sec with 64k memory per channel, time domain reflectometry (TDR) with normalization, 10 psec time interval accuracy, and more.

HP 54111D: the hot single shot.

The HP 54111D offers two simultaneous channels operating at up to 1 Gigasample per second...allowing you to capture high-speed single-shot phenomena such as high-speed pulses, plasma discharge, high voltage arcing, high frequency bursts, laser pulses and high energy events.

You get the single-shot performance of analog storage oscilloscopes with all of the performance advantages of digitizing oscilloscopes.

The HP 54111D also offers a 500 MHz bandwidth, so it will perform admirably in a wide variety of repetitive as well as non-repetitive applications.

HP 54112D: 64,000 bytes times 4.

The HP 54112D offers you simultaneous 4-channel capture at 400 Megasamples per second with 64k of memory per channel. Just right for the long data streams found in serial data communication applications.

HP 54111D

- ☐ 1 Gigasample/sec digitizing rate
- ☐ 500 MHz repetitive bandwidth
- ☐ 250 MHz single-shot bandwidth
- ☐ 8k memory per channel
- ☐ 1 mV/div sensitivity

HP 54112D

- ☐ 400 Megasamples/sec digitizing rate
- ☐ 100 MHz repetitive or single-shot
- ☐ 4 simultaneous channels
- ☐ 64k memory per channel

rmance digitizing oscilloscopes.

Four simultaneous channels enhance critical timing measurements on multiple test points...single-shot. And the HP 54112D's four channels are always real-time correlated for every trigger occurrence.

In automated test, four channels with 64k memory per channel boost your throughput by capturing 256k of data simultaneously.

HP 54120T: excels in high-speed applications.

With its 20 GHz bandwidth and 10 psec accuracy, the HP 54120T lets you measure propagation delays of ICs or switching times of high-speed diodes. Characterize microwave switches. Verify signal path impedances in computer backplanes and test fixtures. And more.

You get high sensitivity, resolution, and accuracy for repeatable time-interval and voltage measurements, with stability and ease-of-use comparable to lower-performance oscilloscopes.

The HP 54120T offers four channels for logic gate characterization. Time and voltage histograms to help you quantify noise and jitter. Normalization to correct for imperfect connectors in reflection (TDR) and transmission measurements. Probing to 6 GHz. And the list goes on.

Contact HP today!

For more information on our new high-performance digitizing oscilloscopes, fill out and mail the postage-paid reply card today. Call us direct at **1-800-367-4772, Ext. 215L**. Or contact your local HP sales office listed in the telephone directory white pages. Ask for the electronic instruments department.

HEWLETT PACKARD

HP 54120T

- ☐ dc-20 GHz bandwidth with averaging
- ☐ 10 psec time interval accuracy
- ☐ 0.25 psec time interval resolution
- ☐ Time and voltage histograms
- ☐ Stable TDR with normalization
- ☐ 0.4% voltage accuracy
- ☐ 4 channels

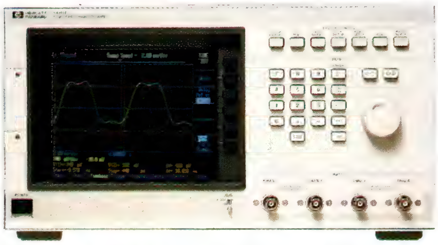
The specs you need, and the features you want.

In addition to their outstanding individual contributions, the new HP 54111D/54112D/54120T digitizing scopes offer you full programmability, automatic measurements, instant hardcopy output to printers and plotters, waveform storage, and multiple-color displays.

You also have HP's excellent reliability, documentation, and support to make you productive with your HP instrument quickly and ensure your satisfaction for years to come.

we never stop asking

"What if..."



HP 54111D $23,900.00*

VERTICAL	
Rep. bandwidth	500 MHz
S.S. bandwidth	250 MHz
Inputs	2 chan & 2 trig
Resolution	8 bit to 25 MHz, 7 bit to 100 MHz, 6 bit to 250 MHz
Sensitivity	1 mV/div to 5 V/div
Coupling	ac, dc; 50 Ohm & 1 MOhm
HORIZONTAL:	
Digitizing rate (max)	1 GSa/sec
Resolution	10 psec
Pre-trigger viewing	YES
MEMORY:	
Acquisition/chan	8k
Waveform storage	2 pixel, 4 rep wfm, 4 ss wfm
Nonvolatile instrument setups	10

HP 54112D $22,900.00*

VERTICAL:	
Rep. bandwidth	100 MHz
S.S. bandwidth	100 MHz
Inputs	4 chan & 1 trig
Resolution	6 bit to 100 MHz
Sensitivity	5 mV/div to 5 V/div
Coupling	ac, dc; 50 Ohm & 1 MOhm
HORIZONTAL:	
Digitizing rate (max)	400 MSa/sec
Resolution	40 psec
Pre-trigger viewing	YES
MEMORY:	
Acquisition/chan	64k
Waveform storage	2 pixel, 4 rep wfm, 4 ss wfm
Nonvolatile instrument setups:	10

HP 54120T $27,850.00**

VERTICAL:	
Rep. bandwidth	20 GHz
S.S. bandwidth	NO
Risetime	17.5 psec
Accuracy	0.4%
Inputs	4 chan & 1 trig
Resolution	12 bits
Sensitivity	1 mV/div to 80 mV/div
Coupling	50 Ohm
HORIZONTAL:	
Accuracy	10 psec
Resolution	0.25 psec
Pre-trigger viewing	NO
Range	10 psec/div-1 s/div
MEMORY:	
Acquisition/chan	0.5k
Waveform storage	2 pixel (volatile), 4 rep wfm (nonvolatile)
Nonvolatile instrument setups:	10
TDR	
Pulse source	
Amplitude	0-200 mV
Risetime	35 psec
Flatness	1%
Normalization	YES
Waveform histograms	YES

*U.S. list price only.
Varies according to options selected.
**U.S. list price only.
Includes both the HP 54120A and HP 54121A.
Specifications subject to change without notice.

DESIGNED FOR HP-IB SYSTEMS

HP-IB: Not just IEEE-488, but the hardware, documentation and support that delivers the shortest path to a measurement system.

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Tokin Magnetic Linear Encoders work like nothing else.

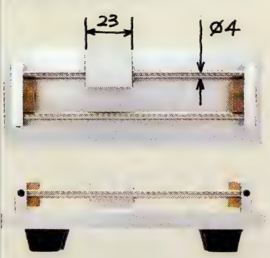
Tokin high-resolution Magnetic Linear Encoders are made from Fe-Co-Mn magnetic alloy, a new high-performance recording medium, and feature magnetoresistant detection heads for monitoring the speed and position of moving domains on rods magnetized at fine pitches.

These encoders come in two low-cost, compact series. MLE-P, for printers and plotters, can be easily installed without changing the existing design, and provide direct detection of printer head position for superior print quality. MLE-D Series, for disk drives and card readers, let you combine magnetic scale and guide shaft for greater miniaturization of disk drives, and function as an external scale for high-speed random access.

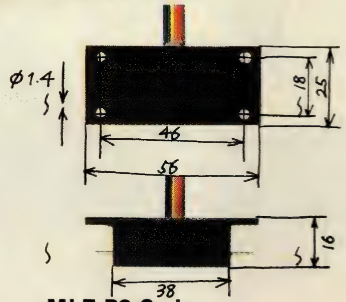
Tighten up your act with Tokin. Call us right now.

Shapes and Dimensions

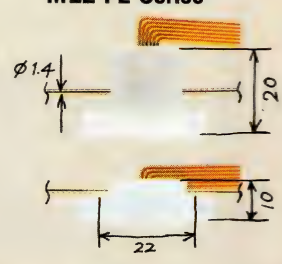
MLE-D Series



MLE-P1 Series



MLE-P2 Series



[mm]

Characteristics

Output signal

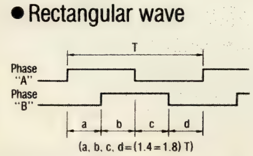
- Approximate sine wave with 2 phases shifted 90° V(p-p) = 400mV (min.) (Spacing: 50μm)
- Rectangular wave with 2 phases shifted 90° (MLE-P1 Series only)

Signal frequency

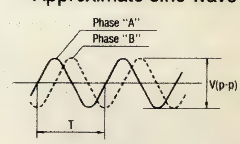
1) T = 1/120 inches (211.7 ± 10μm)
2) T = 1/90 inches (282.2 ± 10μm)
3) T = 1/60 inches (423.3 ± 10μm)

Waveform

- Rectangular wave



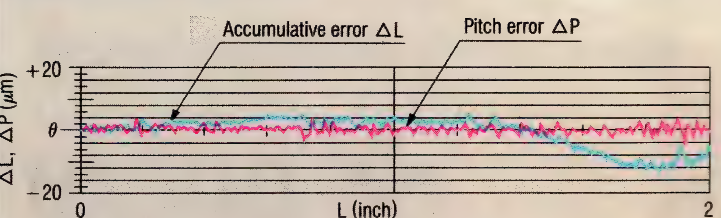
- Approximate sine wave



Specifications

	MLE-P1 Series	MLE-P2 Series	MLE-D Series
Cumulative error	50μm or less/200mm		
Magnetic scale diameter	ø1.4		ø3.0 or ø4.0
Magnetic scale length	800mm (max.)		120mm (max.)
Response frequency	50kHz (min.)	200kHz (min.)	
Power supply	+5V DC ±10%		

Accuracy measurement data



Accumulative error = distance (measured by standard scale) − distance (measured by the Tokin linear encoder)
Pitch error = pitch (detected by the Tokin linear encoder) − set pitch

CIRCLE NO 19

Tokin

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Head Office
Hazama Bldg., 5-8, Ni-chome, Kita-Aoyama, Minato-ku, Tokyo 107, Japan
Tel: Tokyo (03) 402-6166 Fax: Tokyo (03) 497-9756
Telex: 02422695 TOKIN J

Tokin America Inc.
2261 Fortune Drive, San Jose, California 95131, U.S.A.
Tel: 408-432-8020 Fax: 408-434-0375

Chicago Branch
Presidents Plaza 1, Suite 200N, 8600 W. Bryn Mawr, Chicago, IL 60631
Tel: 312-380-0030 Fax: 312-693-8334

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Elisabethstraße 21, 8000 München 40, Bundesrepublik Deutschland
Tel: (089) 271 75 22 Fax: (089) 271 75 67 Telex: 5 24 537 tokin d

You can reach our agents by phone: London 01-837 2701; Paris 1-45 34 75 35; Milan (0331) 678.058; Munich (089) 5164-0; Seoul (02) 777-5767; Taipei (02) 7311425; Hong Kong 3-315769; Singapore 747-8668

Gould cell compilers give you something rarely found with complex ASICs.

Enough time.

Time to squeeze more functions onto the die, to create new cells, to tweak old cells for more performance. Time to avoid the compromises deadlines can cause. All it takes is Gould's EXPERT ASIC™ cell compilers and services.

No compromises. No limits. Done in no time.

EXPERT ASIC tools create cells in one-tenth the time. Generate PLAs. Create ROMs and RAMs with custom word-size configurations. There's even a new datapath compiler for DSPs coming soon. And they'll all work with over 200 existing digital cells and megacells, including bit-slice μPs.

Even analog functions are easier. Custom filters can be generated in hours. Op amps, too. It's like having an unlimited library at your disposal. And mixed-mode designs have never been quicker.

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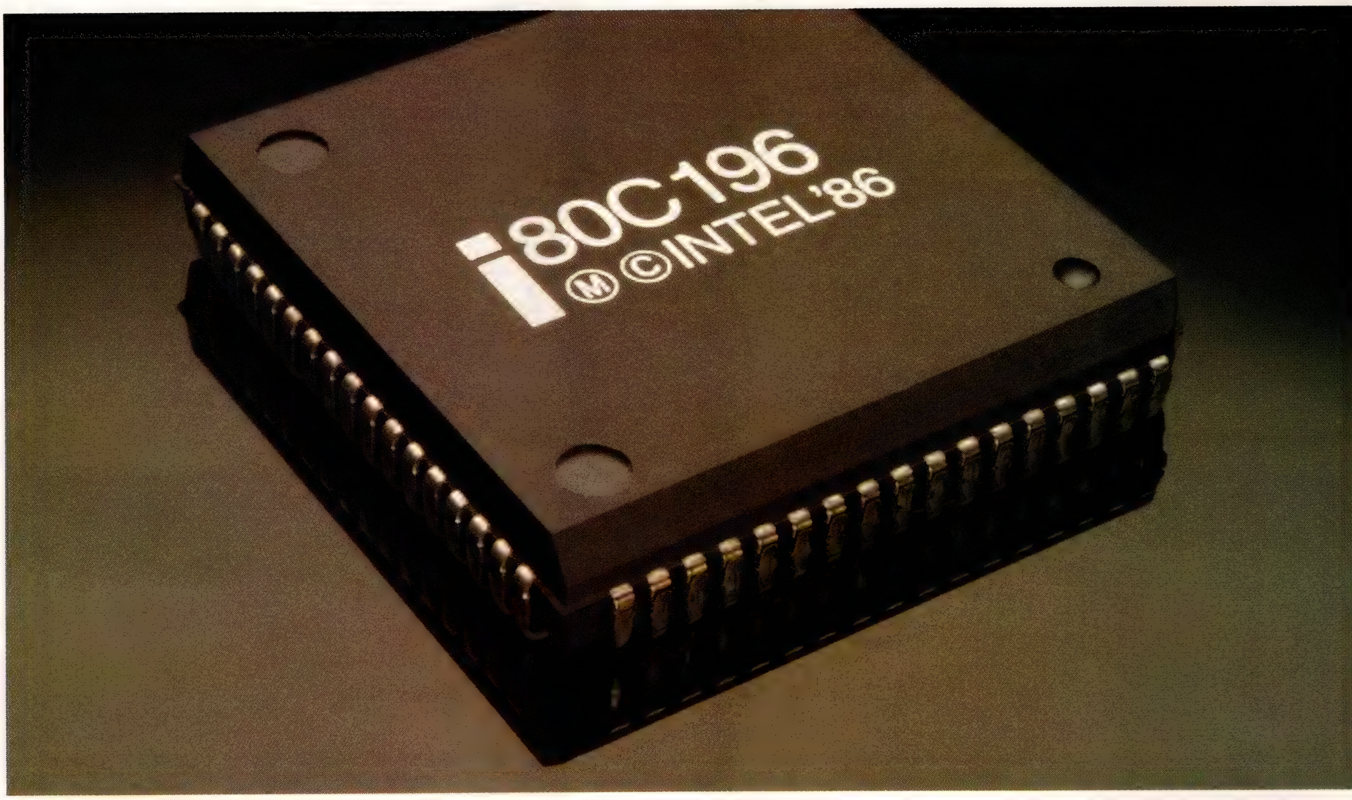
Manufacturer of Gould AMI Semiconductors.

GOULD
Electronics

FOR REAL-TIME DESIGNERS THAT DEMAND THE MOST, THE CONTROLLER THAT DEMANDS THE LEAST.



Our new 80C196 delivers the highest performance and the highest integration of any 16-bit microcontroller available. While demanding the least power, the least design time, the

least hassle. Which means you can spend more time perfecting the rest of your application.

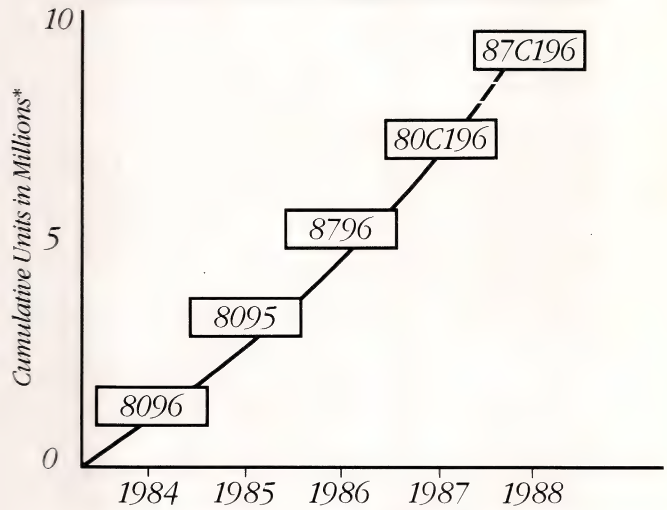
The 12 MHz 80C196 is the latest member of our proven MCS-96 family of embedded controllers. It offers the low-power requirements of CMOS technology while doubling the performance of the 16-bit 8096. Which means that it can perform a 16 x 16 multiply in 2.3 microseconds. That's faster than any other microcontroller.

Yet you still get all the features of the 8096. And more. Resident on the highly-integrated 80C196 are a 16-bit cpu with an 8/16-bit bus (reconfigurable), 256 bytes of RAM, PWM, 10-bit A/D, two 16-bit timer/counters, 40 I/O pins, full duplex serial port, and a high-speed I/O subsystem. And speaking of getting more features in less space, we're working on an EPROM version of the 80C196 for an even easier design path (available Q2 1988).

Our low cost ICE™-196 PC development tool gives you more for less, too. Together with high-level languages like PL/M and C, it delivers the easiest, lowest-cost design support you can get.

Further support is available from the world's largest network of field applications engineers. Plus customer workshops to get you up to speed fast.

8096 FAMILY OF 16-BIT EMBEDDED CONTROLLERS



*Includes proprietary products based on 8096 architecture

So you see, there's really no easier or more powerful answer to embedded real-time control than Intel's 80C196. For complete technical information, call toll-free (800) 548-4725 and ask for Literature Department W398.

Do it now. And relax.

Because we're ready to meet your demands.

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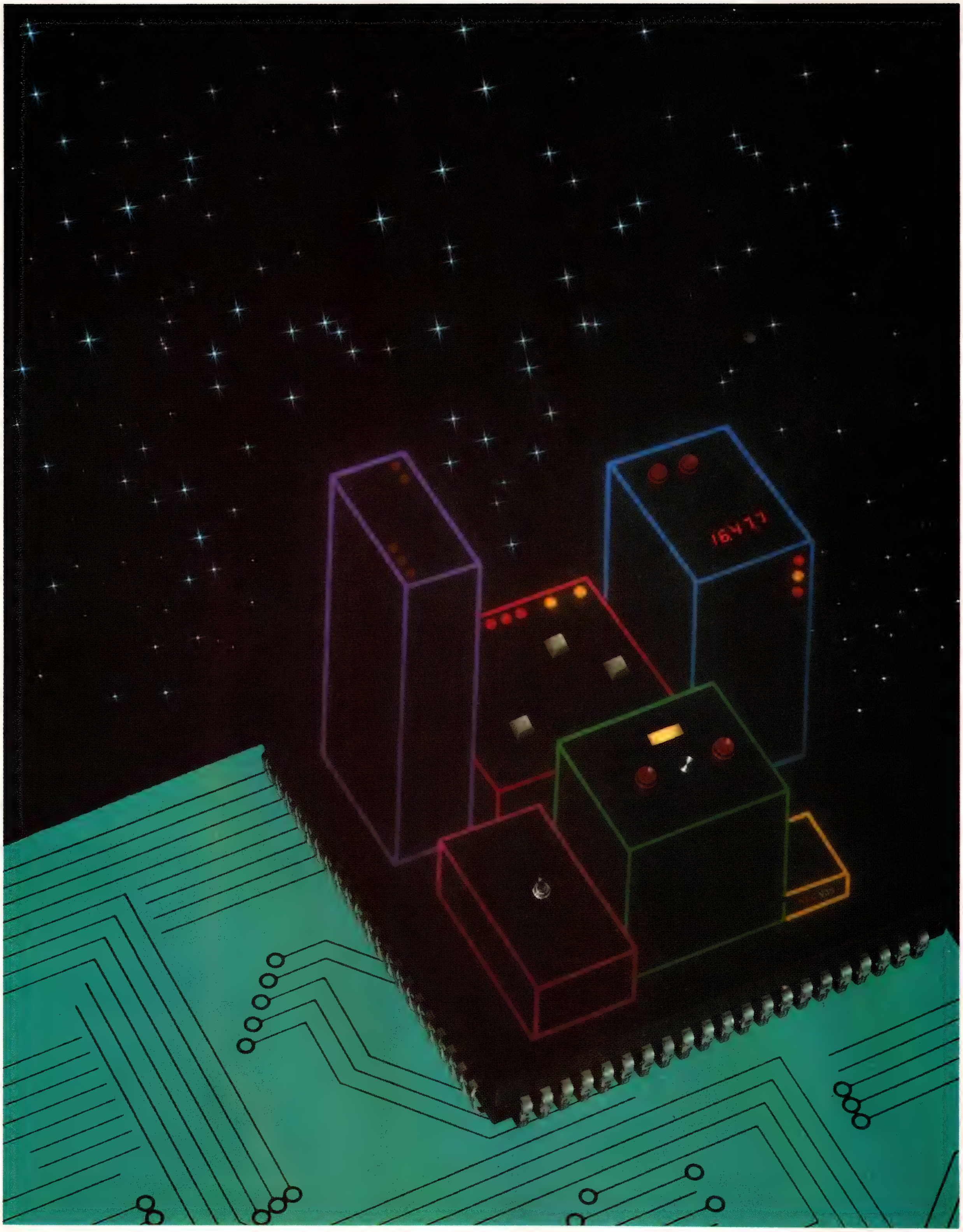
CIRCLE NO 75

Selecting the right single-chip microcontroller for an embedded-control application is not an easy task, because many of the cost and performance features of 4-, 8-, and 16-bit devices overlap.



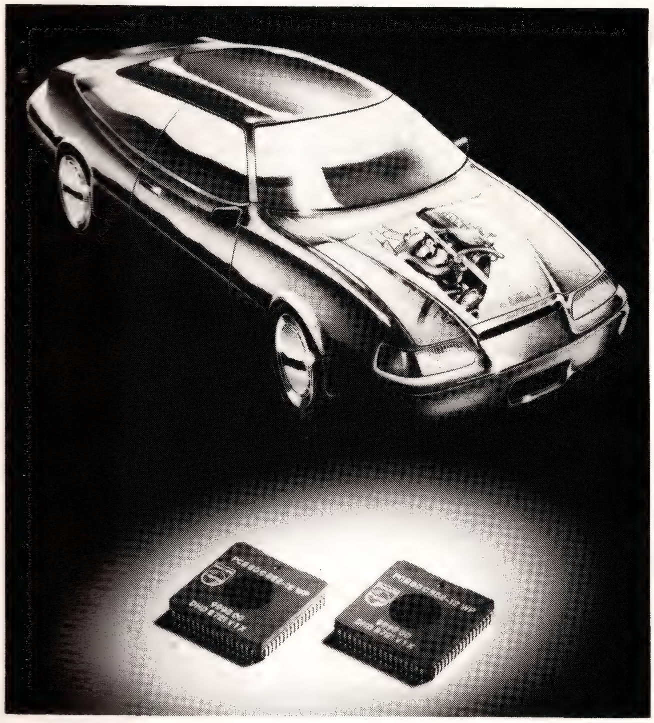
A look inside the modern microcontroller *unveils the complexity and capabilities of the device. (Photo courtesy NEC)*

Special Report

Enhanced microcontroller chips

John Gallant, *Associate Editor*

The ubiquitous single-chip microcontroller continues to be the designer's choice for intelligent control applications. Today's microcontrollers are resplendent with on-chip peripherals that meet the specific requirements of most embedded systems. These peripherals—enhancements to the computing cores—make the controllers suitable for use in cost-sensitive applications (such as TV tuners, VCR controllers, and automotive circuits) as well as in performance-driven applications (in which, for instance, a microcontroller might unload burdensome duties from a telecommunication system's central processing unit). Selecting the right controller for a particular task, however, is often bewildering. You not only have to determine whether you need a 4-, 8-, or 16-bit device, you also have to choose among an assortment of instruction sets.



Microcontrollers, such as the PCB80C552 *from Philips, find their way into many of today's automotive embedded-control applications.*

The 4-bit marketplace is still active

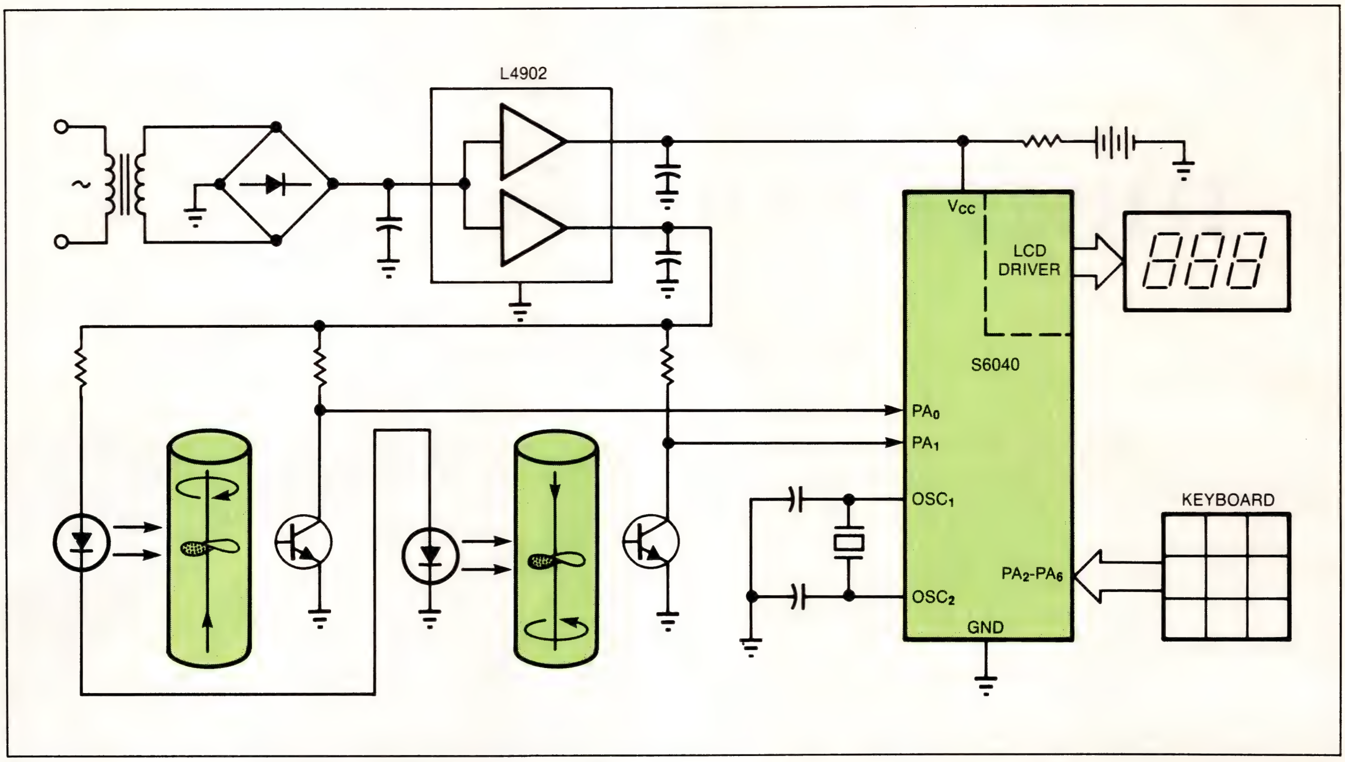
Four-bit microcontrollers have evolved far beyond their origins as control chips in calculators. They offer a low-cost solution for timing, counting, and control functions. Some devices, such as National's COP413L, sell for less than $0.50 each in large volumes. These devices have limited on-chip features, however, such as 0.5k-byte ROM, 32×4-bit RAM, 16 I/O lines, no interrupts, and no timer/event counters. Other devices that have more on-chip horsepower but are still designed for low-performance applications can cost as much as $2.

One such microcontroller is NEC's μPD7556; it has a 1k-byte ROM, 64×4 bits of RAM, 20 I/O lines, two testable interrupts, four analog comparator inputs, and an 8-bit timer/event counter. The 24-pin CMOS device operates over a 2.5 to 6.0V power-supply range and has two standby modes (stop and halt) to reduce power consumption. An external resistor can set the instruction cycle time to 4 μsec, or the chip can operate from an external clock with a period of 2.86 μsec. The unit costs $1.60 (100,000); the mask charge is $2500.

The 4-bit microcontroller families that are designed for low-cost applications generally have instruction cycle times exceeding 2 μsec. Microcontroller chips from Toshiba's TLCS-42 and TLCS-47 families, National's COP400 family, and NEC's 7500 family are examples. Some members of these families have ROMs as large as 4k bytes and as much as 256×4 bits of RAM.

As LSI manufacturing technology has advanced, companies have been able to offer higher-performance 4-bit microcontroller families competitive with low-end

You can choose from a wide variety of microcontroller architectures: After deciding on 4-, 8-, or 16-bit devices, you'll face an assortment of instruction sets.



An application using an S6040 *from SGS Semiconductor Corp calculates the difference between two flow sensors to indicate the fuel consumption of LCD displays.*

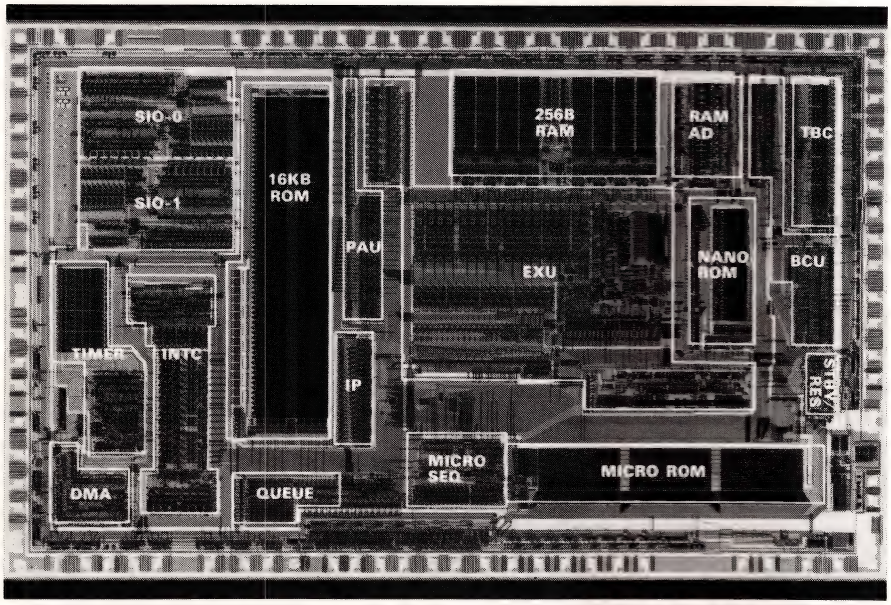
8-bit controllers. The NEC μPD75000 family and Toshiba's TLCS-470 family are positioned in this class. The μPD75000 members have instruction cycle times less than 1 μsec, and the TLCS-470 devices offer instruction cycle times of 1.33 μsec. NEC's μPD75308 has 8k bytes of ROM, 512×4 bits of RAM, 32 memory-mapped I/O lines, three external and three internal vectored interrupts, an 8-bit timer/event counter, 32 LCD drivers, a watchdog timer, and an instruction set that can manipulate data in 1-, 4-, or 8-bit units. The 80-pin, $4 (100,000) CMOS device operates over the 2.7 to 6.0V range.

Hitachi's HD4074408 and HD4074008 are μPs designed for the higher-performance 4-bit market. Each features 8k×10 bits of ROM, 512×4 bits of RAM, and 58 I/O lines. The ROM is a one-time-programmable (OTP) device, which eliminates the need to wait three or four months to receive masked-ROM devices. You can use an industry-standard 27256-type EPROM programmer and socket adapter to program these ZTAT (zero turn-around time) CMOS devices. The instruction cycle time of the HD4074008 is 0.89 μsec; for the higher-speed HD4074408, it's 0.5 μsec. Both devices come in 64-pin plastic DIPs, ceramic DIPs, or plastic surface-mount packages; operate from 5V (±10%); and feature two low-power modes.

The $15.65 (1000) HD4074008 has 12 high-current (15 mA) outputs, two timer/event counters, an 8-bit serial interface, and a 16-level subroutine stack. The $17.21 (1000) HD4074408 provides eight high-voltage (12.8V max) outputs, 16 high-current (100 mA) outputs, two separate 8-bit serial interfaces, four comparator inputs, a 16-level subroutine stack, and four timer/event counters, two of which can provide PWM outputs. All of the NEC 4- and 8-bit microcontrollers are available with OTP ROM.

Both 4- and 8-bit chips aim for same market

Because of the maturity of some 8-bit microcontroller families, some of these devices are now priced low enough to compete in the 4-bit marketplace. Intel's 8048 and one of Zilog's Z8 family, the Z8600, sell for about $1 in OEM quantities. Intel's 8031 chip is priced under $1.50 in OEM quantities. Although these devices don't have the on-chip output-drive capabilities of the mature 4-bit families, they do combine powerful on-chip computing and data-handling features with extensive instruction sets.



Sixteen-bit microcontrollers, *such as NEC's V25, are amply equipped to handle high-speed, high-performance tasks.*

SGS, which is an alternate source for the Z8 family, has aimed its 8-bit S6 microcontrollers at the cost-sensitive market. All the members of this family are designed around an S6 core and run at 5 MHz. Each has an 8-bit timer/event counter, a watchdog timer, and an 8-bit A/D converter, and each provides analog V_{CC} and analog GND pins. The $1.80 (1000) S6011 comes in a 20-pin DIP and contains 2k bytes of program ROM plus 32 bytes of data ROM. The HCMOS part also provides 32 bytes of RAM, seven I/O lines, and three inputs for its A/D converter.

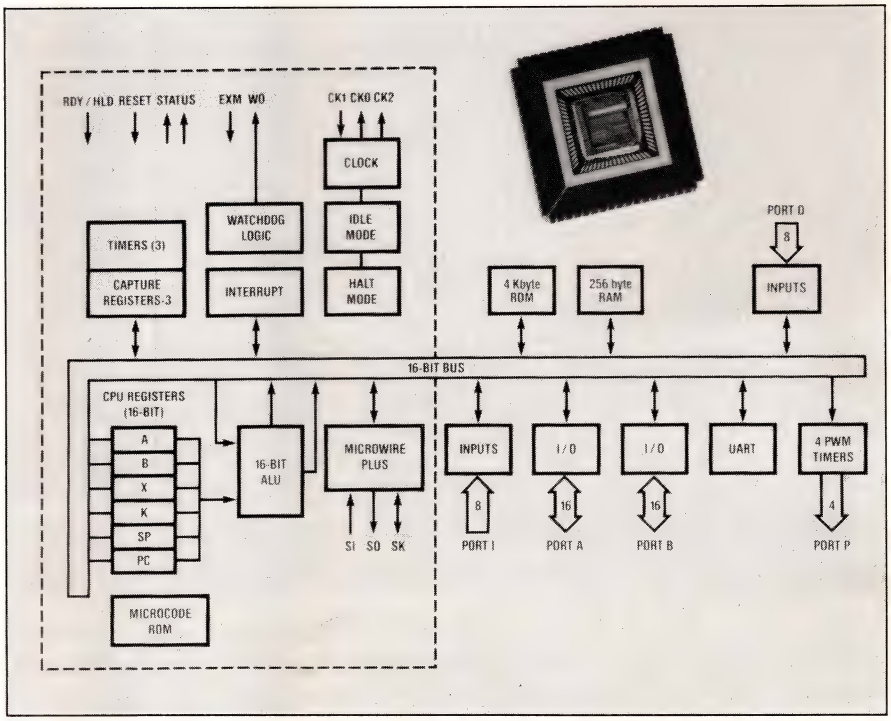
National's COP800 Series also competes in the cost-sensitive 8-bit market. Sierra Semiconductor is an alternate source for many members of this line; the company replaces the COP prefix with an SC4 prefix. For example, the SC44820 is pin and functionally compatible with National's COP820C. Promising an instruction cycle time of 1 μsec, these CMOS parts (which sell for less than $1.50 in OEM quantities) each have 1k bytes of ROM, 64 bytes of RAM, one 16-bit timer/event counter, a Microwire serial I/O interface, and multiple interrupts. They both operate over the 2.5 to 6.0V range. Sierra's SC48720 is an EEPROM version of this part for program development.

When choosing between 4- and 8-bit devices, keep in mind that the 4-bit families are not second sourced, although NEC has multiple factories in Japan producing 7500 and 75000 Series devices. In contrast, most of the low-cost 8-bit microcontrollers are second sourced. The CMOS 80C51, for example, is one of the most popular computing core structures for many newer microcontrollers. Signetics, Siemens, Matra-Harris Semiconductor, and AMD are a few of the companies that are offering this part while developing other enhanced models.

Moreover, keep in mind that writing code for a 4-bit microcontroller is quite different from writing code for an 8-bit one, mainly because the die size of a 4-bit device is smaller than that of an 8-bit device. The ROM size dominates the real estate available on a 4-bit die so that the bit-path architectures are more Harvard-like than Von Neumann-like. The 4-bit devices' instruction sets reflect this difference so that bits, flags, and registers have to be monitored to perform data-manipulation tasks. Because wider bit paths are available on 8-bit dies, many of these overhead tasks are not required, making programming easier.

Sourcing and programming considerations and the near parity with respect to cost suggest that you employ 8-bit controllers even when 4-bit ones might suffice. However, be assured that if you are familiar with an instruction set for a 4-bit device, you'll have to spend time and money learning to program 8-bit ones. In addition, 4-bit devices costing less than $2 still offer more on-chip features than do low-cost 8-bit controllers. You could expect to pay a few dollars more to get equivalent output drivers in most of the newer 8-bit devices.

Many of the newer 8-bit microcontrollers contain higher performance features. Zilog's Super8 family has an improved Z8 instruction set that includes multiply and divide instructions as well as Boolean and BCD



***One trend apparent in many microcontroller** families is the addition of peripherals to a standard computing core. National's HC18083 is one such example.*

operations. Additional instructions that support threaded-code languages, such as Forth, enhance real-time operations. The interrupt structure will handle 27 interrupt sources and eight interrupt levels, and it can provide 1-level servicing in 600 nsec. The device has an on-chip DMA controller that can be used by its UART or a handshake channel to transfer data from a peripheral to either the register file or an external memory. It also has 325 single-byte registers and two, 16-bit timer/event counters, and it runs at either 12 or 20 MHz. The counter/timers are programmable for capturing a count value at an external event or for generating an interrupt whenever the count reaches zero. The Z8820 member of the family has 8k bytes of ROM and costs \$4.95 (100).

Hitachi's latest addition to its HD64180 family is the HD647180X—the first member of its 180-ZTAT Microcontroller Series. The CMOS family is code compatible with Zilog's Z80 CPU and therefore can draw from the large installed base of Z80/8080 software. Key on-chip functions in this family include an MMU (memory-management unit) that addresses 1M bytes of memory, a 2-channel DMA controller, two asynchronous serial interfaces, a dynamic-RAM refresh controller, two 16-bit programmable reload timers (PRTs), and a 12-source interrupt controller. In addition, the HD647180X contains 16k bytes of OTP ROM with data protection, 512 bytes of RAM, a 6-channel analog comparator, 54 I/0 lines (eight of which are high current), and another 16-bit timer with output compare registers. Samples of the chip are available for \$20; production quantities should be available by the end of this quarter.

The ZTAT devices' OTP ROM makes their per-piece cost higher than that for masked-ROM devices. However, if your requirements call for less than 10,000 units, the OTP ROM devices can be cost-competitive; you needn't pay mask charges, and you needn't order a large minimum quantity. Moreover, you won't have to wait for the vendor to fabricate masked-ROM devices.

Even if you select a masked-ROM device for your design, you can considerably shorten the time required for EPROM code verification. Traditionally, code developed for a particular design is shipped to the device manufacturer via an EPROM. The manufacturer then logs the bit patterns into his computer, develops a verification EPROM for the customer to evaluate, and doesn't begin to generate a mask until customer verification is complete. This process can take as long as 10 weeks. However, RCA, which provides microcontroller devices compatible with the Motorola 6805 family, provides a service that can reduce this verification time to hours. If you have a personal computer that contains the Kermit communication protocol, you can send your

Because of the maturity of certain 8-bit microcontroller families, some of these devices are now priced low enough to compete in the 4-bit marketplace.

bit pattern directly to RCA's VAX computer via a modem. The pattern that is logged into the VAX computer is sent back (via modem) for you to evaluate using the PC.

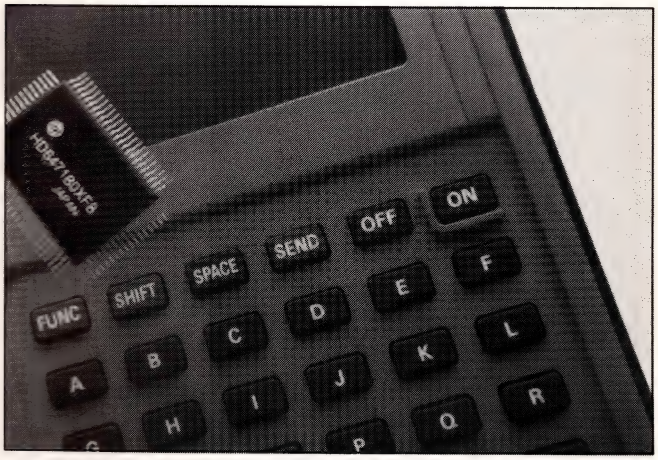
Other companies, including Zilog, provide similar services. Even with such a service, however, you still must wait the time it takes to build masked-ROM devices. Typically, mask development requires five working days, wafer fabrication takes about 30 working days, and packaging and testing take another five days.

New family members want to be heard

The pattern of many microcontroller manufacturers is to develop a family of devices around a standard computing core. Each member of the family is equipped with varying degrees of enhancements. The Mitsubishi 740 family is built around a core that's compatible with the 6502 instruction set. It can take advantage of code that has been written for that popular CPU. The latest members of the CMOS family (the M50930FP, M50931FP, and M50932FP) can control as many as 128 LCD segments while providing low-power battery backup (3V) for portable applications. The devices differ according to the amount of RAM and ROM; they offer 128 to 512 bytes of RAM and 4k to 8k bytes of ROM. The devices each have an 16-bit timer, a UART, and a 2-μsec (min) instruction cycle time. The M50930 costs $6.25 (5000).

Motorola's MC68HC05L6 is another new family member. The 8-bit microcontroller has an on-chip liquid display driver along with 6208 bytes of ROM, 176 bytes of RAM, a serial peripheral interface, a 16-bit timer, and an audio-tone generator. The device is currently available in die form only. The mask charge is $5300, and purchasers must buy at least 1000 units at $12.95 each.

If your requirements demand a standard hardware design with flexible and alterable code configurations, Dallas Semiconductor's DS5000 microcontroller is designed around the popular 80C51 core. A feature of this 8-bit CMOS device is the use of nonvolatile RAM for program and data storage. This feature allows the program memory to be changed at any time via an on-chip serial I/O port that can connect to a host computer via an RS-232C port. Software is also loadable in a parallel mode, which causes the chip to emulate an 8751 for EPROM programmers. An on-chip lithium source provides 10 years of battery backup once an electronic freshness seal is broken. In addition, the chip has two 16-bit timer/event counters, 32 parallel I/O



Featuring a Z80-compatible instruction set, *Hitachi's HD647180X provides 16k bytes of OTP (one-time-programmable) ROM.*

lines, and a watchdog timer, and it provides software security using encryption logic. The 40-pin device costs $78 (100) with 32k bytes of RAM and $59 (100) with 8k bytes of RAM.

Siemens, AMD, and Signetics also offer enhanced versions of the 80C51 microcontroller. Siemens's SAB80515 and AMD's 80C521 each provide 8k bytes of ROM, 256 bytes of RAM, and a watchdog timer. The 68-pin SAB80515 also has 48 I/O lines, an 8-bit A/D converter, and three 16-bit timer/event counters; it can respond to 12 interrupt sources with four priority levels. The chip sells for $11 in minimum quantities of 1000. The 44-pin 80C521 sells for $12.50 (100). Signetics has a number of soon-to-be-released products built around the 80C51. One product that is available now is the 80C451, which costs $7 (100). It has 4k bytes of ROM, 128 bytes of RAM, and two 16-bit timer/event counters, and it provides 56 I/O lines in a 68-pin PLCC or 52 I/O lines in a 64-pin DIP.

If you're designing an adaptive machine that learns as it performs its tasks, consider a microcontroller that contains EEPROM. Seeq's 40-pin 72720-16 is compatible with the full instruction set for the 8-bit TMS7000 microcontroller. It contains 256 bytes of RAM and 2k bytes of EEPROM; the EEPROM feature allows the program memory to be altered by the microcontroller itself during program execution or to be changed under external control. A designer using this part can thus create self-adaptive algorithms. The $29.65 (100) NMOS device runs at 16 MHz and provides a security-lock feature to inhibit code access.

Most of the current microcontrollers are being designed with CMOS technology because of the technolo-

If your requirements call for less than 10,000 units, one-time-programmable ROM devices can be cost competitive.

gy's low power consumption and the increased speed relative to NMOS. CMOS devices are inherently more costly than their equivalent NMOS parts, however. CMOS microcontrollers require two FETs to perform the function of one FET in an NMOS device, and therefore CMOS devices require more on-chip real estate than NMOS devices do to perform equivalent functions. The ultimate cost of any microcontroller is the die cost, and larger dies cost more. For this cost reason, some manufacturers, such as Siemens, are committed to supplying NMOS devices as well as CMOS types.

ECL technology is also finding use in microcontrollers. The 8-bit 8X401 from Philips achieves 150-nsec instruction cycle times; it combines ECL circuitry with TTL I/O buffers. Fundamental to this speed is the chip's Harvard architecture, which provides parallel paths for instructions, addresses, and operands. The chip responds to enabled interrupts within two instruction cycles of a request. It contains sixteen 8-bit registers, two user-definable status flags, and three independent I/O banks, each of which can address as many as 256 locations. An external TTL clock with a maximum frequency of 40 MHz derives the timing signals. The 64-pin chip runs off a 5V supply and dissipates 2.5W max. The device sells for DM 17 (100).

As is the case with the cost/performance features of high-end 4-bit and low-end 8-bit devices, the cost/performance features of high-end 8-bit devices overlap those of low-end 16-bit devices. The 16-bit chips are finding uses in high-speed devices such as laser printers and disk drives, and are suitable for high-performance control applications such as satellite receivers, modems, and robotic-assembly-line equipment.

Intel's 80C196 is a CHMOS upgrade of its 16-bit 8096. The 80C196 is pin-for-pin compatible and uses a superset of the 8096 instructions. For a given oscillator frequency, the 80C196's state-time generator operates 1.5 times as fast as the 8096's. With a 12-MHz oscillator, the chip performs a 16-bit addition in 0.66 μsec and a 16×16-bit multiplication in 2.3 μsec; the instruction cycle times average between 0.5 and 1.5 μsec. The chip provides a 232-register file, a full-duplex serial port, a 10-bit ADC with an S/H input, five 8-bit I/O ports, numerous 16-bit timers (including a 16-bit watchdog timer), a PWM output signal, and a dedicated baud-rate generator; an 8k-byte ROM is optional. A 68-pin PLCC version of the chip sells for $29.25 (100).

Many manufacturers are making their computing cores available in cell form for ASIC products. Intel already offers its 80C51 in cell form and plans to have the 80C186 and 80C196 cores available for 16-bit ASIC designs within two years. In addition, the company is providing application-specific standard products (ASSPs) with custom-like features. The ASSPs integrate a standard core with peripherals to create a chip targeted for a particular control application. For example, the 80C152 multiprotocol communications control-

Enhancements to microcontrollers take many forms

Vendors can enhance microcontrollers in many ways. Features you might look for include reduced cost, low power consumption, an expanded temperature range, ease of code development, and interrupt servicing capabilities. In addition, you might look for devices that come in a variety of package types and that are available from alternate sources. You also might want to consider whether a particular computing core is part of or will be included in a standard-cell library for ASIC development.

A list of some of the on-chip peripheral functions that manufacturers are placing around computing cores follows (you can expect such a list to continue to grow as vendors strive to meet customer demands):

- A/D converters
- Analog comparators
- Audio-tone generators
- D/A converters
- DMA controllers
- DTMF generators
- Dynamic-RAM controllers
- High-current drivers
- High-voltage drivers
- ISDN channel interfaces
- LED drivers
- LCD drivers
- Multiple I/O lines
- Phase-locked-loop controls
- Piggyback EPROM
- Pulse-width-modulation outputs
- Timer/event counters
- UARTs
- Vacuum-fluorescent-display drivers
- Watchdog timers

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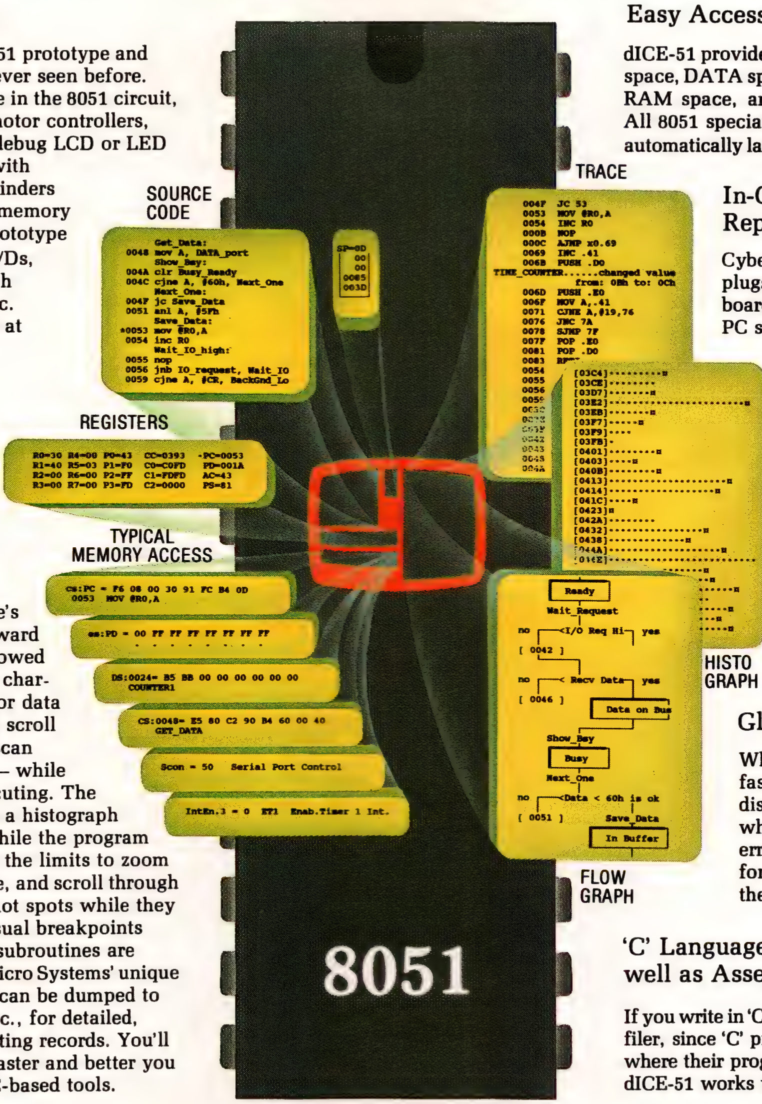
In-Circuit Debugging

Plug dICE-51 into your 8051 prototype and you'll see things you've never seen before. dICE-51 executes I/O Code in the 8051 circuit, so that when you debug motor controllers, motors move! When you debug LCD or LED controllers, pixels flash; with pneumatic controllers, cylinders extend. You can exercise memory mapped I/O and access prototype RAM, ROM, Switches, A/Ds, D/As, etc. Compatible with 8051, 8052, 8031, 8751, etc. (CMOS versions available at extra cost).

Powerful, Dynamic User Interface

The user interface is identical to Sim8051 v3.0, which received PC Tech Journal Magazine's "Product of the Month" award for its unique, multi-windowed dynamic interface. Single character commands prompt for data if required, while you can scroll through source code and scan symbol space at any time – while stopped, stepping, or executing. The Execution Profiler creates a histograph that varies dynamically while the program executes. You can change the limits to zoom in on regions of code space, and scroll through the source code to study hot spots while they execute. Of course, the usual breakpoints and conditional visibility subroutines are built in, with Cybernetic Micro Systems' unique FlowGraph windows that can be dumped to IBM printers, Laserjets, etc., for detailed, commented, self documenting records. You'll be amazed at how much faster and better you design with these 8051 PC-based tools.



Easy Access to all 8051 Spaces

dICE-51 provides easy access to CODE space, DATA space, BIT space, External RAM space, and Special Function space. All 8051 special bits and registers are automatically labeled when you access them.

In-Circuit Element Replaces 8051

Cybernetic's unique CY8051 chip plugs into your 8051 prototyping board which connects to your PC serial port.

Live Keyboard, Displays, Everything

The dICE-51 keyboard is always 'live', allowing you to scroll through the source code, scan symbols, or change bits or bytes, even while your program is running. Execution Histographs and Interrupt Count summaries are updated while your program executes.

Global Symbol Monitor

When single stepping, and after fast execution, dICE-51 will display every named variable whose value was altered. Spot errors as they occur! Don't wait for a subsequent crash and then try to backtrack.

'C' Language Support as well as Assembly

If you write in 'C', you need an execution profiler, since 'C' programmers have no idea where their program spends the most time. dICE-51 works with Archimedes 'C-51'.

Complete 8051 Design Support

dICE-51 Debugger with In-Circuit-Element consists of one disk and one chip. No computer slot, no umbilical cord, no pod or ICE box. CY8051 IC element plugs into your 8051 socket. You connect your application circuit to your PC's COM 1 and the dICE software communicates over the RS 232 port. 8051 strobes such as WR and RD preserve timing, but port I/O instructions run at the reduced rate characteristic of Sim8051.

$795

CYS-8051 Cross Assembler produces LST and HEX files from ASM files. The Intel HEX code files are compatible with most EPROM equipment.

$295

SIM-8051 A superb 8051 debugger that offers all features of dICE-51 except the In-Circuit-Element. The system Cycle Counter Register can provide timing accurate to one 8051 instruction cycle.

$595 Demo Disk $39

CYP-8051 8751, 87C51 and 27xx EPROM Programmer Kits – low cost EPROM Programming with all functions available from within CYS-8051 Cross Assembler.

$245 kit form $395 assembled

PROTO-51 An 8051 Prototyping Kit is available.

Software not copy protected.

☐ Rush free data sheet on dICE-51 and 8051 tools.
☐ Send $10 User Manual.
☐ Send $39 dSim8051 (User Interface demo disk & Manual)
☐ Send $795 dICE-51 plus $5 shipping.
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Many microcontroller manufacturers are developing families of devices around standard computing cores.

ler, based on the 80C51 core, lets the designer manage various communication protocols with a single chip. It is suited for implementing ISDNs, LANs, and user-defined backplane communications. It has two on-chip DMA channels, an MCS-51-compatible UART, and a serial communications I/O port that supports SDLC, HDLC, and CSMA/CD protocols. It is available in a 48-pin dual-in-line package and a 68-pin surface-mount PLCC. It sells for $25 (10,000).

National Semiconductor expects future microcontroller designs to use a standard-cell core surrounded by customized peripherals on an ASIC chip. The glue logic will be implemented with gate arrays. The core will consist of fixed CPU functions, including CPU registers, a microcode ROM, an ALU, serial interfaces, interrupt logic, and a clock. You'll be able to add other functions, such as UARTs, timers, ADCs, and PLLs. The benefit of this approach is to allow the designer to standardize on one or two powerful CPU cores for integration of specific functions on one chip. Development tools and emulators cannot handle every conceivable customized configuration, however, so designers must develop new tricks to check out a design.

National's HPC16083 16-bit microcontroller is a member of the HPC family of standard-core devices. The core will be available in National's standard-cell library. The standard version uses a 17-MHz clock and has a 16-bit CPU with six working registers, 8k bytes of ROM, 256 bytes of RAM, 52 I/O lines, eight 16-bit timers, four input-capture registers, and a UART. A 30-MHz version achieves instruction cycle times of 134 nsec. It has a trio of low-power modes: normal (250 mW), halt (100 mW), and stop (50 μW). The 84-pin chip has a Microwire/Plus serial bus interface for communi-

Manufacturers of microcontrollers

For more information on microcontrollers such as those mentioned in this report, contact the following manufacturers directly or circle the appropriate numbers on the Information Retrieval Service card.

Advanced Micro Devices Inc
Box 3453
Sunnyvale, CA 94088
(408) 732-2400
TLX 346306
Circle No 701

Dallas Semiconductor Corp
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Dallas, TX 75244
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Hitachi America Ltd
Semiconductor and IC Div
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Circle No 703

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Chandler, AZ 85226
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TWX 602-961-2674
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Matra-Harris Semiconductor
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TLX 299656
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Mitsubishi Electronics America Inc
Semiconductor Div
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Sunnyvale, CA 94086
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TWX 910-339-9549
Circle No 706

Motorola Inc
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TLX 384467
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Toshiba America Inc
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(714) 832-6300
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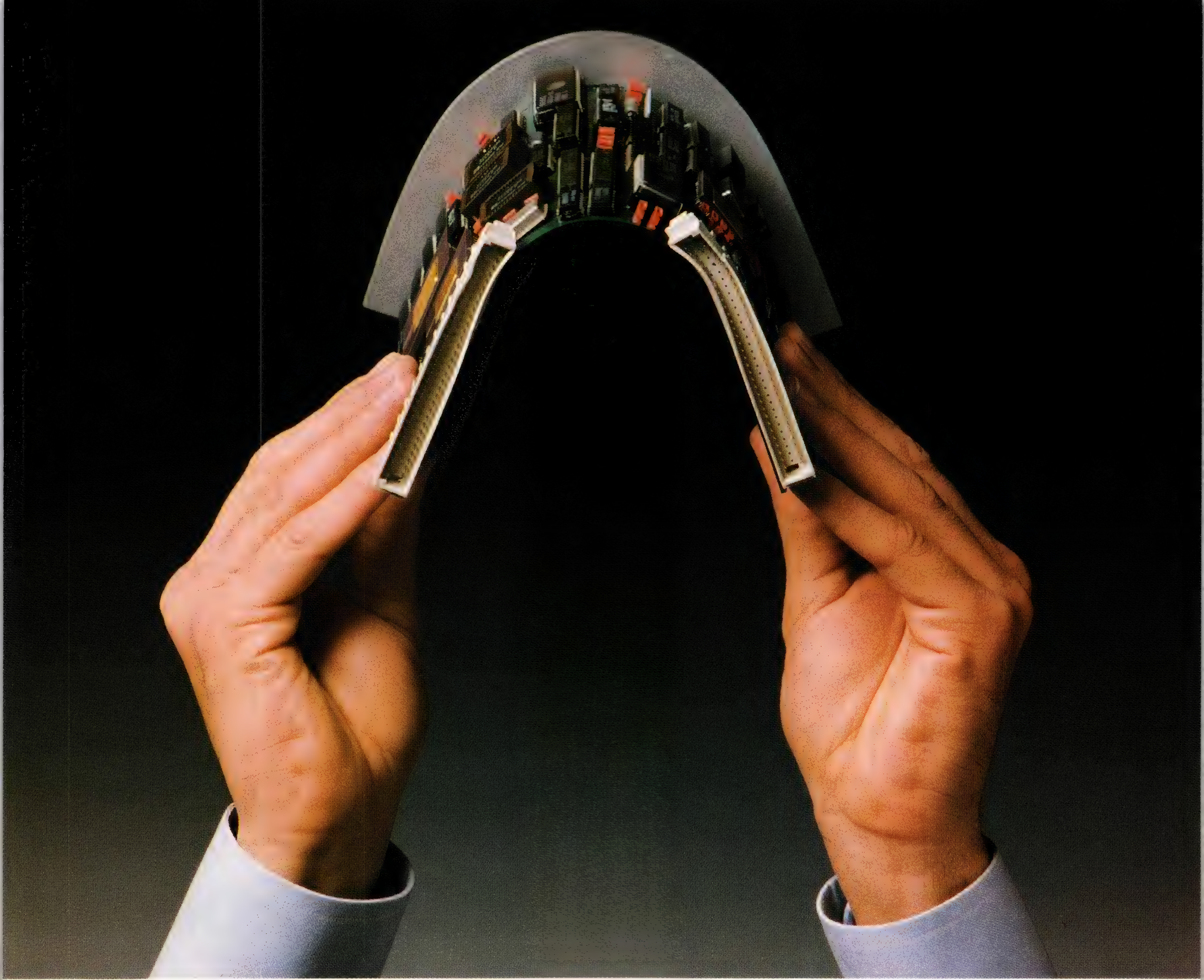

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CIRCLE NO 77

Most of the current microcontrollers are designed with CMOS technology.

cation with off-chip peripherals. A 17-MHz version costs \$10.20, and a 30-MHz version costs \$13.60 (10,000).

Some vendors compete for the triple crown

National, Mitsubishi, and NEC all offer 4-bit, 8-bit, and 16-bit families. Mitsubishi's M37700M2 is a 16-bit microcontroller with an instruction set that's upward compatible with its MELPS740 8-bit line. The 80-pin chip provides 16k bytes of ROM, 512 bytes of RAM, 68 I/O ports, an 8-bit A/D converter with eight inputs, two UARTs, a watchdog timer, and eight 16-bit timers. The chip can service 19 interrupts over eight priority levels, and an on-chip MMU allows memory expansion to 16M bytes.

NEC's 78000 Series includes 16-bit microcontrollers that support 16- and 8-bit external architectures and maintain 16-bit on-chip data paths and 20-bit address paths. The μPD70332 (V35) has all the features of the μPD70322 (V25), but the latter's external bus is 16 bits wide rather than eight. These devices use an instruction set that is upward compatible with the 8086/8088 software. The 20-bit address bus lets the chip address a 1M-byte address space. Both devices include 16k bytes of ROM, 256 bytes of RAM, two UARTs, 24 I/O ports, two timer/event counters, and eight analog comparator ports, and both can service 17 interrupt sources with eight priority levels. The \$25 (1000) V35 includes an on-chip dynamic-RAM controller; the \$20 (100) V25 has two DMA controllers. **EDN**

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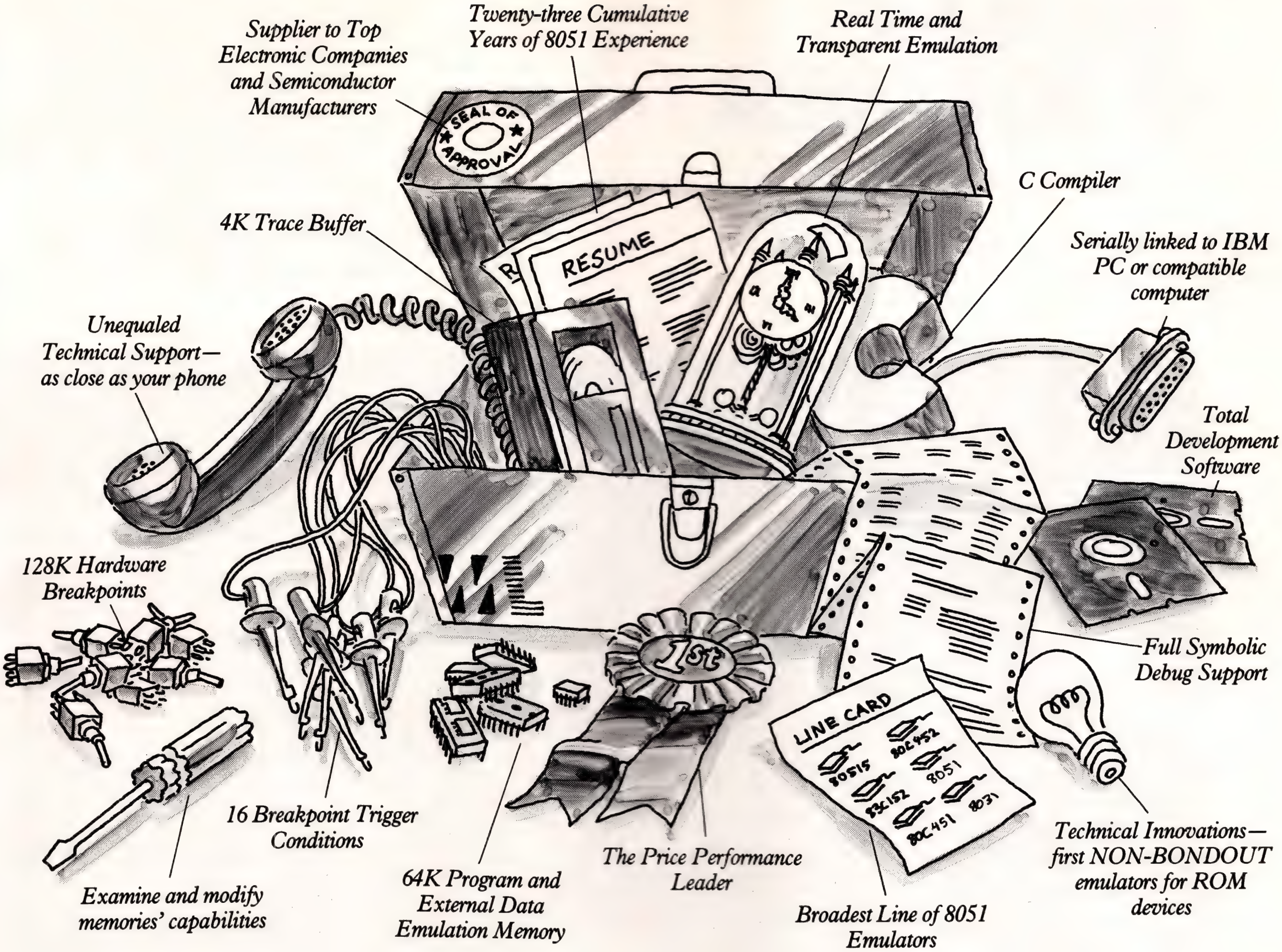

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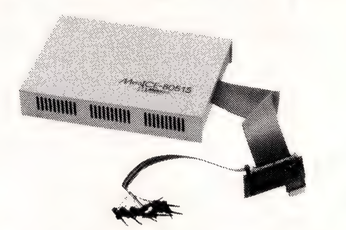

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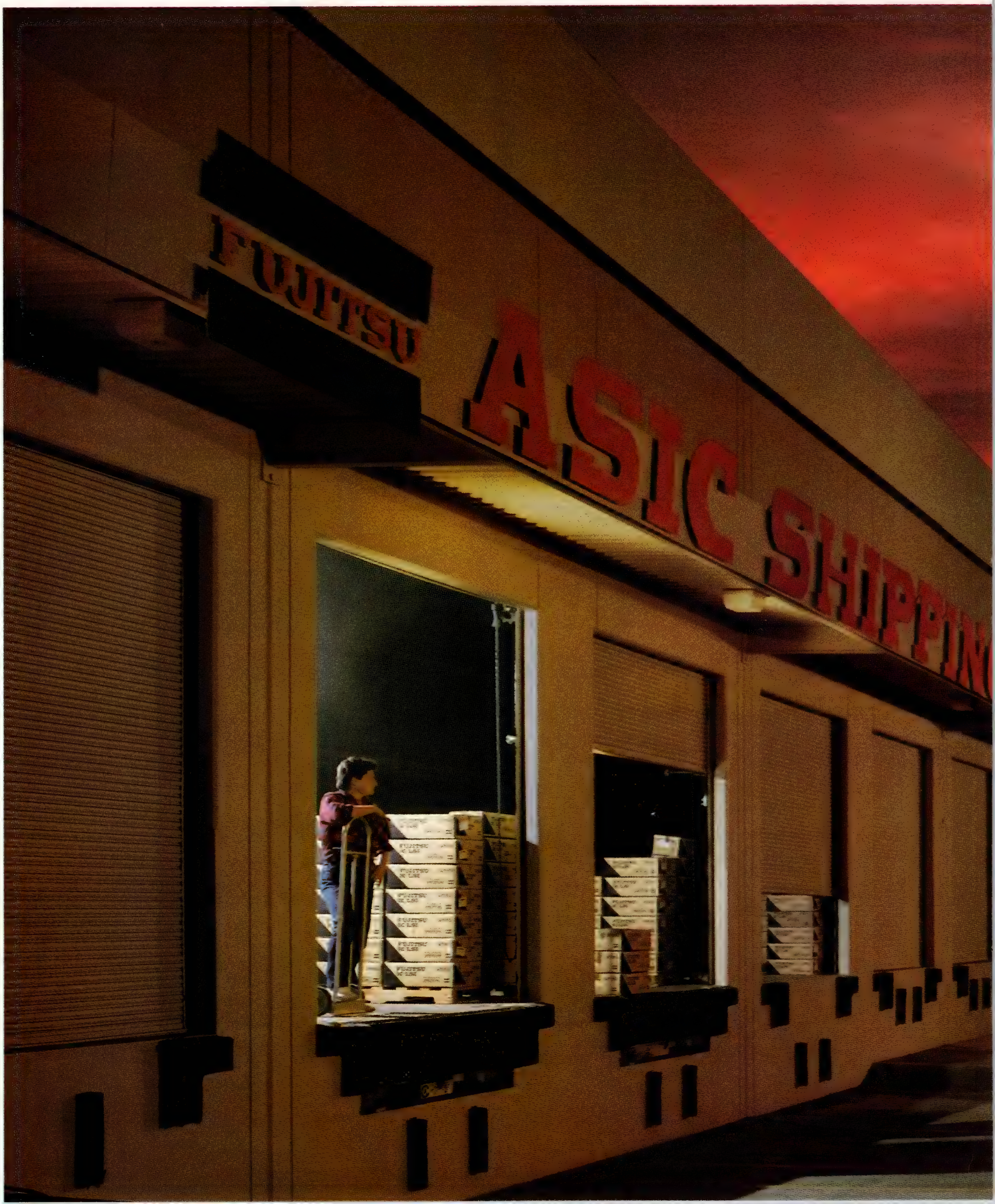

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Understand CMOS flash ADCs to apply them effectively

Although they resemble each other superficially, CMOS and bipolar flash A/D converters are in fact quite different. These two converter species have distinct operational characteristics. You need to understand the internal structure of CMOS flash ADCs before you can apply them effectively.

Michael J Demler, *Datel*

The dissimilar comparator circuits of CMOS and bipolar flash converters account for the marked differences in these devices' linearity, maximum conversion rate, and power dissipation. To obtain maximum performance from your CMOS flash converter, you must understand these differences.

The most critical components in any flash A/D converter are its comparators. Bipolar devices' comparators typically use a differential pair of transistors (**Fig 1**) in which one base connects to the input signal and the other ties to a reference voltage.

Ideal divider creates 1-LSB increments

Each comparator has a different reference voltage, obtained from taps on a resistive voltage divider. Adjacent taps on the precision, resistive voltage divider determine these voltage levels; in the ideal case, the levels are 1 LSB (least significant bit) apart, producing a unique output code for each quantization level. Different manufacturers use various metallization techniques to fabricate these voltage dividers.

The transistors' parameters determine the dynamic performance of flash converters constructed as in **Fig 1.** At a given bias current, the comparator's gain-bandwidth product determines the converter's conversion speed and maximum input frequency. Further, the continuous dc-bias currents required for bipolar converters account for the fact that bipolar converters exhibit high power dissipation in comparison with that of CMOS devices.

The reference transistor's base current loads the resistive divider. Combined with the transistors' offset voltage, this loading effect degrades the dc linearity of a bipolar flash converter.

The bipolar transistors' nonlinear input capacitance affects the bipolar converter's ac linearity. Both the

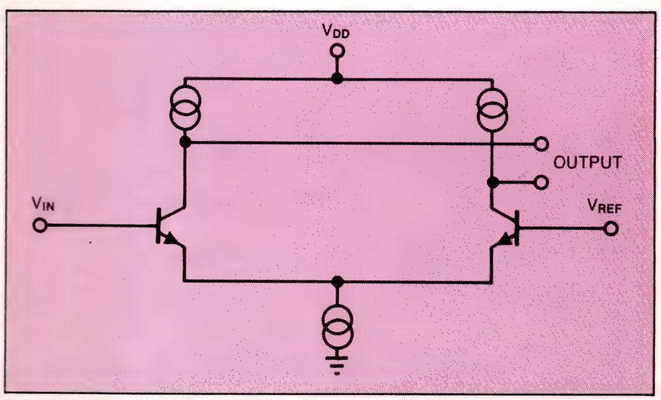

***Fig 1—The dynamic performance of this bipolar** comparator depends on the transistor parameters and their level of bias current.*

A buffer amplifier's attributes combine with a flash converter's input impedance to limit the converter's analog-signal bandwidth.

required, external buffer amplifier and the converter's reference-voltage resistive divider must drive this nonlinear capacitance, which can vary by a factor of four over the bipolar device's specified frequency range. What's more, nonlinearity in this capacitance creates a variable RC-charging time at the comparator inputs that can distort high-frequency signals and impair the external input-buffer amplifier's stability.

CMOS flash A/D converters do not have these problems. The CMOS comparator has a high input impedance whose variation with frequency is linear. The comparators in CMOS flash converters do not present a dc load to their reference divider and so don't distort the reference voltages. Unlike a bipolar comparator, an autozeroed CMOS comparator can reduce its own input-offset voltage to an insignificant level—less than 1 mV. And a CMOS comparator is fast; its output switches from rail to rail with the speed of a logic gate (See **box,** "Anatomy of a CMOS flash converter.")

Because CMOS flash converters are inherently sampling devices, their dynamic performance differs dramatically from that of their bipolar cousins. When sampling a signal, the CMOS device presents an input consisting of a parallel array of linear capacitors, rather than the highly nonlinear capacitance presented by a bipolar flash converter.

Different classes of specs

As a consequence of bipolar and CMOS converters' different input circuits, the critical specifications for these two types of converters take different forms. The bandwidth of a bipolar converter, for instance, is often defined in terms of its 3-dB point, in accordance with the bipolar comparator's gain roll-off at higher signal frequencies. When using such devices, you should be aware of the attenuation, A, (in dB) for other frequencies f_{IN}:

$$A = -20 \log \sqrt{1 + (f_{IN}/f_{3\,dB})^2}$$

Attenuation of 1 dB (approximately 10% attenuation), for example, occurs at half the 3-dB frequency in a bipolar flash converter. In a CMOS converter, however, the comparators' sampling nature theoretically provides a flat frequency response for input signals at, and below, the Nyquist frequency (half of the sampling

Anatomy of a CMOS flash converter

CMOS flash A/D converters have significant internal differences from bipolar A/D converters. The ADC207 7-bit flash converter and ADC208 8-bit flash converter from Datel, for instance, employ a CMOS logic gate **(Fig Aa)** (instead of a differential transistor pair) as a high-gain analog circuit.

As you can see in **Fig Ab**, connecting the inverter's input to its output (by closing the autozero switch) biases the inverter at the point on its voltage-transfer curve where V_{IN} equals V_{OUT}. By design, this point is very near to ½ V_{DD}. Moreover, the steepness at this point on the curve represents high gain, because a small change in V_{IN} causes V_{OUT} to make an abrupt transition to one of the two logic levels. (Because

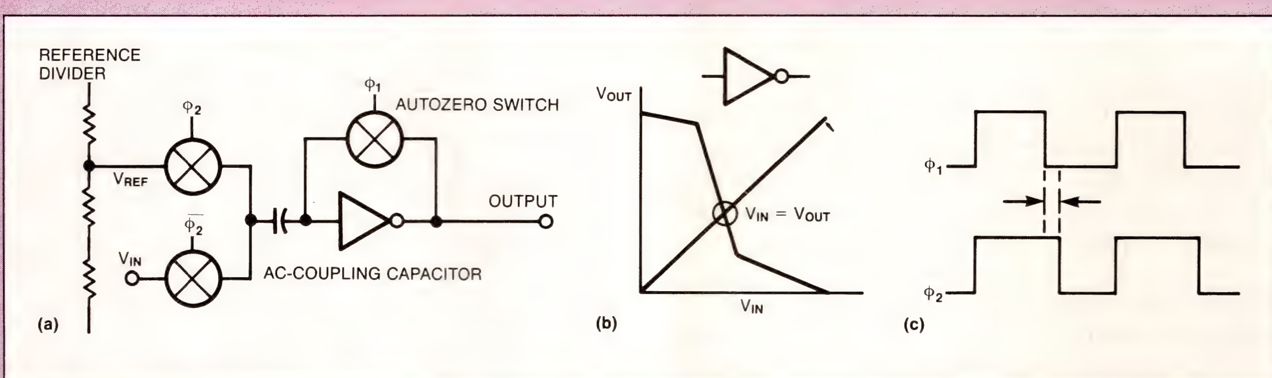

Fig A—The heart of a CMOS flash converter *is a logic gate employed as a high-speed analog element. This circuit combines comparator, sample/hold, and autozero functions.*

rate). Three limitations, however, prevent many CMOS flash converters from achieving this performance:

- The input-frequency roll-off that results from the interaction of the sampling-switch resistance and the input capacitance
- The buffer amplifier's limited ability to drive the converter's input capacitance (comprising the parallel capacitors in the comparators' inputs)
- The comparators' limited ability to track high-slew-rate input signals, given a finite aperture time.

The ADC208 CMOS flash converter, however, minimizes frequency attenuation below the Nyquist limit because its 3-dB frequency is well above the highest clock frequency. The device also avoids the problems that arise when you charge large ac-coupling capacitors through high on-resistance switches; the device's ac-coupling capacitors spec only 0.25 pF.

Finite aperture time limits bandwidth

As noted, a CMOS sampling comparator's inherent sample/hold function should theoretically allow the device to digitize signal frequencies as high as the Nyquist limit. This performance is difficult to achieve in practice, however. An ideal circuit samples the input instantaneously, but a CMOS comparator must track the input signal for a finite sampling interval, called the aperture time. The finite aperture time creates a problem.

As the frequency of a full-scale input signal approaches the Nyquist limit, the waveform, by definition, passes through a half cycle (from V_{REF-} to V_{REF+}) between samples. The comparator output must not only slew through this range during the aperture-time interval (typically half the clock period), but the comparator must also settle within ½ LSB to preserve the converter's accuracy. CMOS sampling comparators have a very nonlinear response, however, and many can't slew fast enough to track V_{IN} under these conditions.

Comparator-output saturation imposes another limitation on the converter's maximum frequency. The input represents substantial overdrive for those comparators whose reference voltage differs greatly from V_{IN}. Their outputs may approach saturation as a result, removing the comparators' operating points from the narrow high-gain region. Consequently, for a given

---

these conditions bias each comparator at its own high-gain point, dc-offset voltages are not a concern—hence the term "autozeroed").

Comparators balance

After the autozero switches close, while the comparators autobias (bias themselves) to their high-gain points, another analog switch connects the ac-coupling capacitor to the reference divider. The capacitor charges up. When the autozero switch opens, the capacitor retains a voltage equal to the difference between the reference voltage and the comparator's bias point. Consequently, the comparator's output remains balanced between the two logic levels even though the comparator's input is no longer clamped to its output.

Opening the autozero switch creates a potential source of error that can disturb the bias point. Stray capacitance between the switch's input and output can allow clock-signal transitions to couple charge into the sensitive input node, producing an offset voltage. Properly designed clocking circuits, however, can eliminate most of this error. In addition, the reference switch remains on momentarily while the autozero switch is turning off (**Fig Ac**), providing a path through the low-impedance ladder to ground. This path allows the discharge of residual error voltages stored on the capacitors.

Finally, the input-sampling switch turns on when the reference and the autozero switches are off. The comparator's open-loop gain now amplifies any difference between the input signal and the reference level, resulting in a latched logic level at the output. Depending on the level of the input signal, some of the comparators will latch in the high state, some in the low state. By finding the boundary between the high and low comparators, you can infer that the analog input voltage lies somewhere between the two specific reference-voltage levels of the comparators at the boundary.

The steep portion of an inverter gate's transfer function represents high gain, because a small change in V_{IN} causes V_{OUT} to assume one of the two logic levels.

frequency and aperture time, these comparator outputs may not settle quickly enough to meet the converter's accuracy spec.

Signal buffer drives dynamic capacitance

A converter's external buffer amplifier, too, is a critical system component. The amplifier's attributes combine with the converter's input impedance to limit the converter's analog-signal bandwidth.

Your choice of input buffer amplifier is critical for all flash-converter applications, because the converters' dynamic input impedance presents a difficult load for the amplifier. For the CMOS device, you can expect better amplifier stability because the device's input capacitance remains constant as the dc-signal level changes. At high sample rates, however, you must account for the comparator inputs' sampling behavior.

When the CMOS converter initiates a sampling period, internal switches immediately connect all input capacitors to the signal buffer's output. Each capacitor

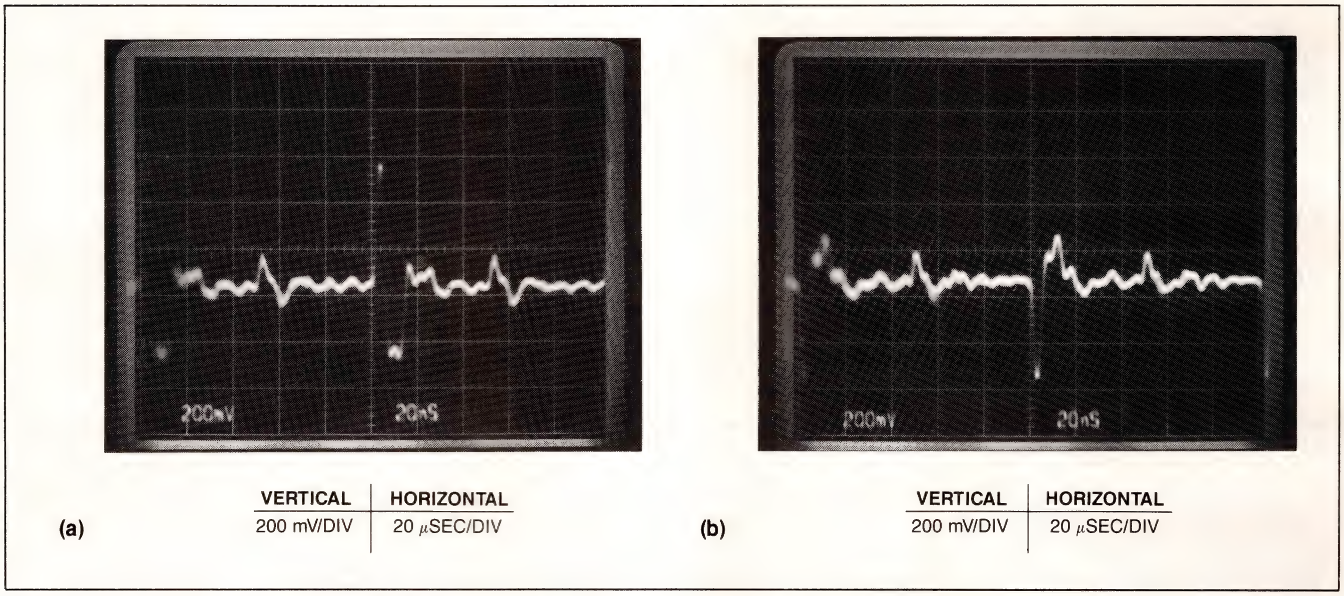

Fig 2—These voltage spikes appear at the output *of a buffer amplifier while it drives a CMOS flash converter during a conversion. The $V_{IN}=V_{REF-}$ case appears in **a**, and the $V_{IN}=V_{REF-}$ case in **b**.*

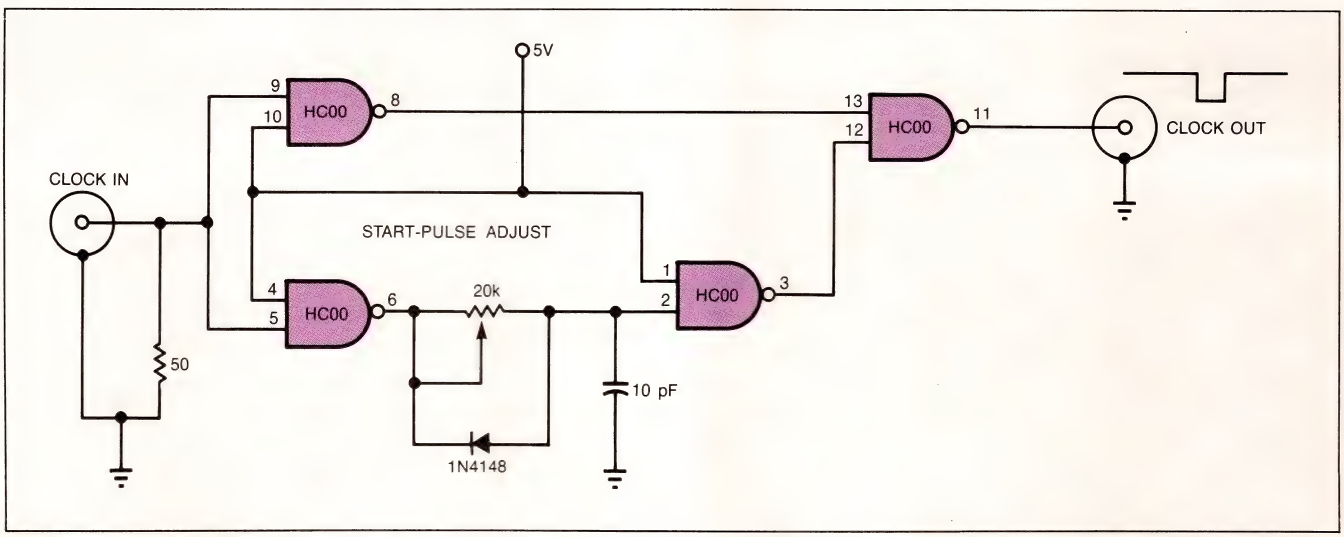

Fig 3—For each negative transition of the clock *signal, this circuit provides a negative, adjustable-width pulse (the min width is 10 nsec).*

has been precharged to the difference between ½ V_{DD} and the reference-tap voltage for that capacitor, creating a sequence in which adjacent-capacitor voltages differ by 1 LSB. Only one of these capacitors has been precharged to within ½ LSB of V_{IN}. All the capacitors must discharge to the V_{IN} level, and the input buffer amplifier must source or sink the discharge currents. The result is a spike at the analog input whose magnitude and direction varies according to the magnitude of V_{IN} **(Fig 2).**

The condition $V_{IN}=V_{REF-}$ creates a positive spike because the buffer must source current to all the capacitors, and $V_{IN}=V_{REF+}$ results in a negative spike because the buffer must sink current. The condition $V_{IN}=½V_{REF}$ biases equal numbers of capacitors above and below the signal level, so the capacitor-discharge currents cancel. To minimize these disturbances and achieve the highest possible sampling rate, you should choose a buffer with low output impedance and a wide bandwidth. The outputs of the LH0033 or EL2003 buffers, for example, will settle in 10 to 20 nsec when driving a CMOS A/D converter.

Pulse sets aperture time

The low portion of the clock waveform sets the ADC208's aperture time. You can adjust that time interval by using a simple circuit **(Fig 3)** that produces pulses as short as 10 nsec. The special precautions common to other CMOS devices for avoiding latch-up are unnecessary for the ADC208, because the gain of parasitic SCRs in the part is insufficient for latch-up.

By adjusting the clock signal for optimum dynamic performance, you can use an ADC207 or ADC208 to digitize inputs having frequencies well beyond the Nyquist limit. This capability is useful, for example, in conducting an envelope test **(Fig 4).** By applying a frequency slightly above the Nyquist frequency, you force the converter to take consecutive samples at nearly 180° intervals on the input waveform. These samples reproduce the envelope, or beat frequency

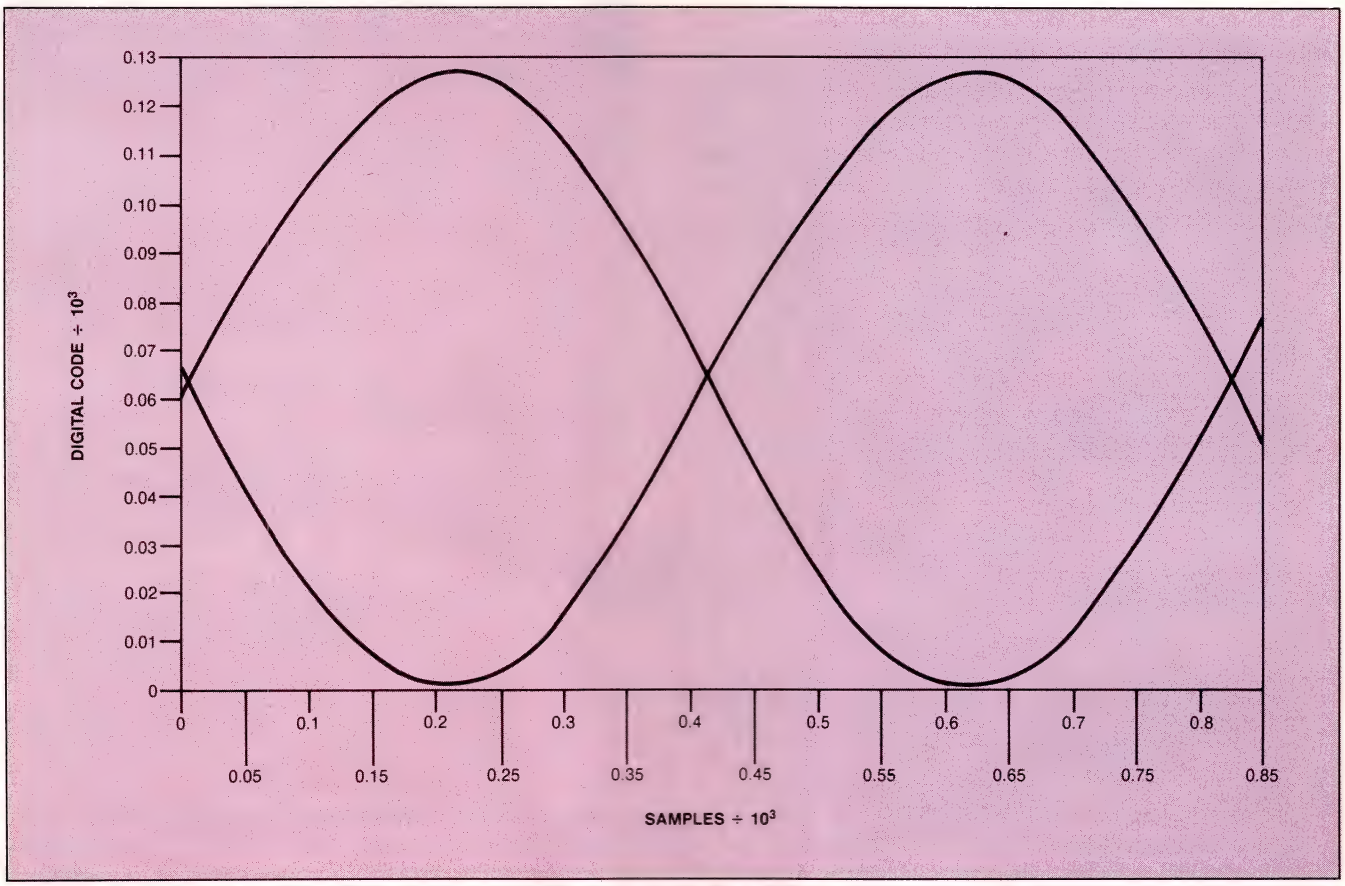

Fig 4—In this envelope test, *the ADC207 flash converter digitizes a sine wave whose frequency is slightly above the Nyquist limit. Consecutive samples occur at 180° intervals on the input waveform, producing these sine waves, whose frequency is* $f_{IN}-f_{NYQUIST}$.

By comparing each comparator's output to that of the adjacent comparators, you can infer that the analog input voltage lies between two specific voltage levels.

($f_{IN}-f_{NYQUIST}$), in the form of two sine waves that are 180° out of phase with each other. This test shows you how well an ADC slews, because the converter must take consecutive samples at opposite extremes of its input range.

Reducing power consumption

You can reduce the ADC208's power dissipation in applications that don't require continuous conversion or the highest possible sample rate. Lowering the supply voltage, for example, lowers the bias current that flows during the converter's autozero period. The ADC208 can operate with a supply voltage as low as 2V; at 2.5V it provides a conversion rate of 10M samples/sec while drawing 20 mA of supply current.

If your application doesn't require continuous sampling, you can also reduce power dissipation in a CMOS flash converter by modifying the clock signal's waveform. (Most of the converter's power dissipation occurs during the autozero interval, while the clock signal is high.)

Double-pulse clock signal saves power

The double-pulse, one-shot circuit of **Fig 5** lets a CMOS flash converter operate with less power while maintaining a high sample rate. The circuit produces first a high pulse that autozeros the converter, then a low pulse that initiates the sample, and then a second high pulse that internally latches the converter's output data. The clock signal then goes low again to minimize power dissipation, and the digital-output drivers remain in the high-impedance state until you're ready to acquire additional data.

If power dissipation is not a concern, but your application demands a maximum data rate, you can remove

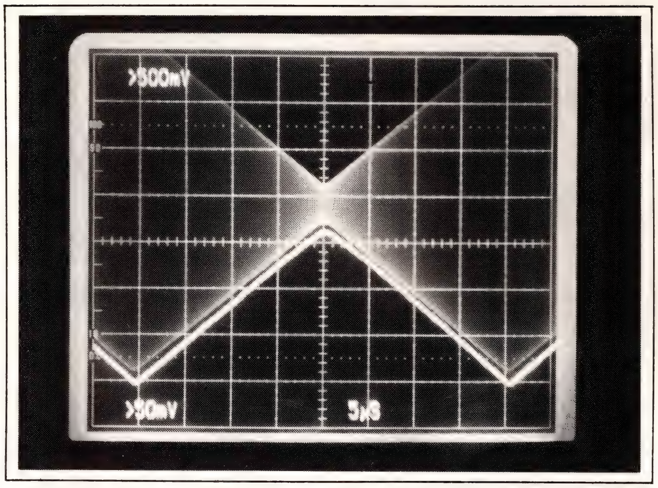

Fig 6—With its sampling clock synchronized *to the input signal (a 10-MHz sine wave modulated by a 25-kHz ramp waveform), a flash converter extracts the ramp (lower trace) by acting as a synchronous demodulator.*

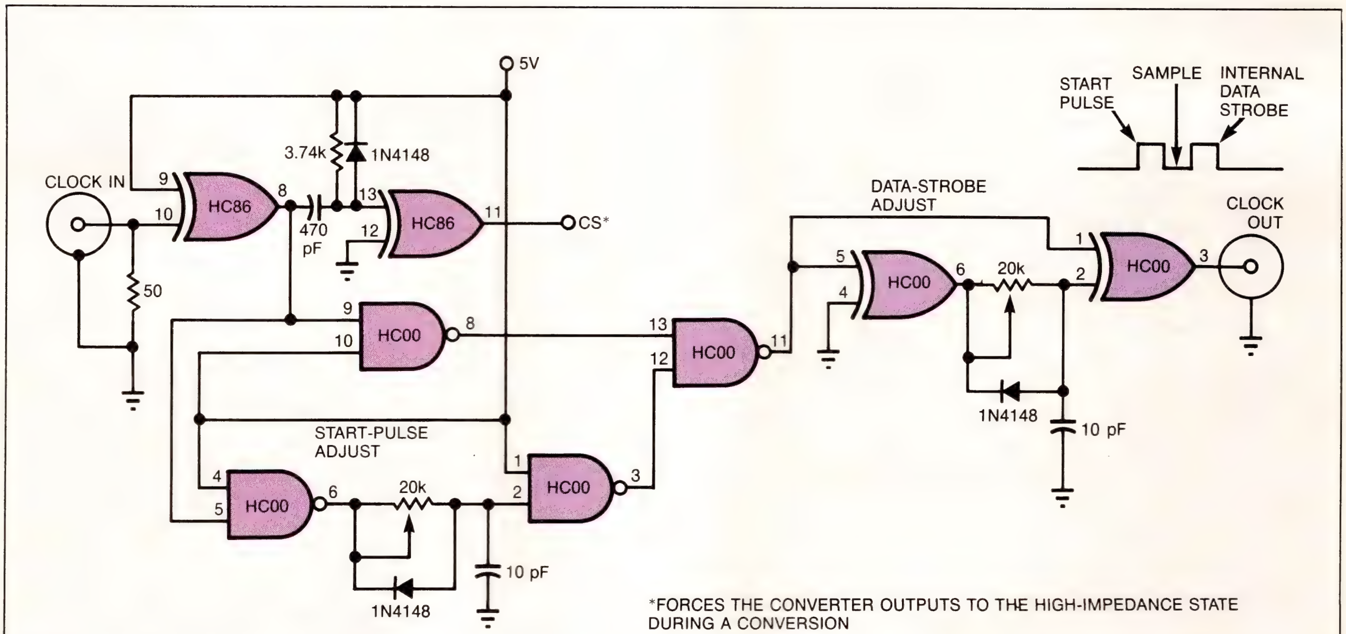

Fig 5—You can reduce power consumption *by driving a CMOS flash converter's clock input with these cascaded one-shots. The highest power dissipation occurs while the clock waveform is high.*

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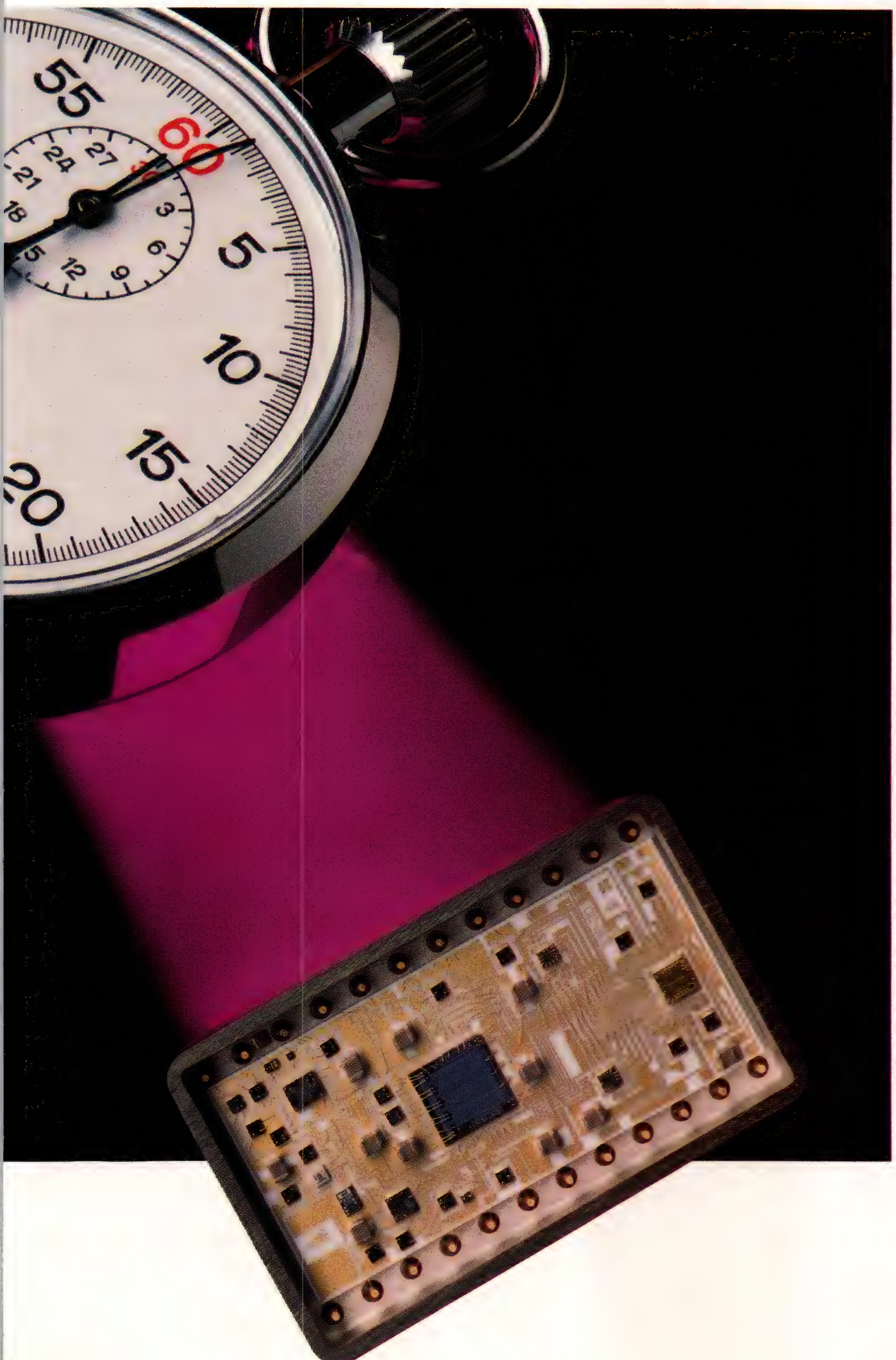

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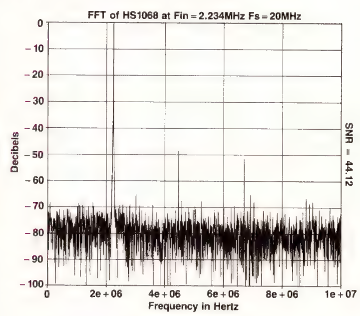

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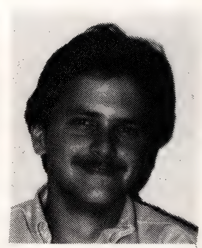
the converter's pipeline delay by applying a different clock waveform. The comparators remain autozeroed while the clock waveform is high. Then, a negative-going pulse as short as 12 nsec initiates a conversion, and the converter output presents valid data 10 nsec after the pulse's positive edge. Thus, you can obtain a data sample as early as 22 nsec after the pulse's leading edge.

Converter serves as AM demodulator

An unusual way to use a flash converter at high conversion rates is to employ it as a demodulator. You lock the input frequency to either the Nyquist rate or the clock rate and then you amplitude-modulate the input with a lower frequency. The converter's high-speed sampling of the carrier (input) signal then produces output codes that represent the modulating envelope. The oscilloscope photo in **Fig 6** shows the input waveform and the recovered modulating signal. In this case, a 25-kHz triangular wave modulates a 10-MHz sine wave that is synchronized to the sampling clock. **EDN**

Author's biography



Mike Demler is the manager of IC design engineering for Datel Inc (Mansfield, MA). He designs high-speed CMOS A/D converters and develops dynamic tests for them. Mike has been with the company for 3 years; he previously worked at General Electric's corporate R&D labs and at Texas Instruments. He earned a BSEE from the State University of New York—Buffalo and an MSEE from Southern Methodist University. He is a member of the IEEE and has had one patent granted. In his spare time, Mike enjoys photography and basketball.

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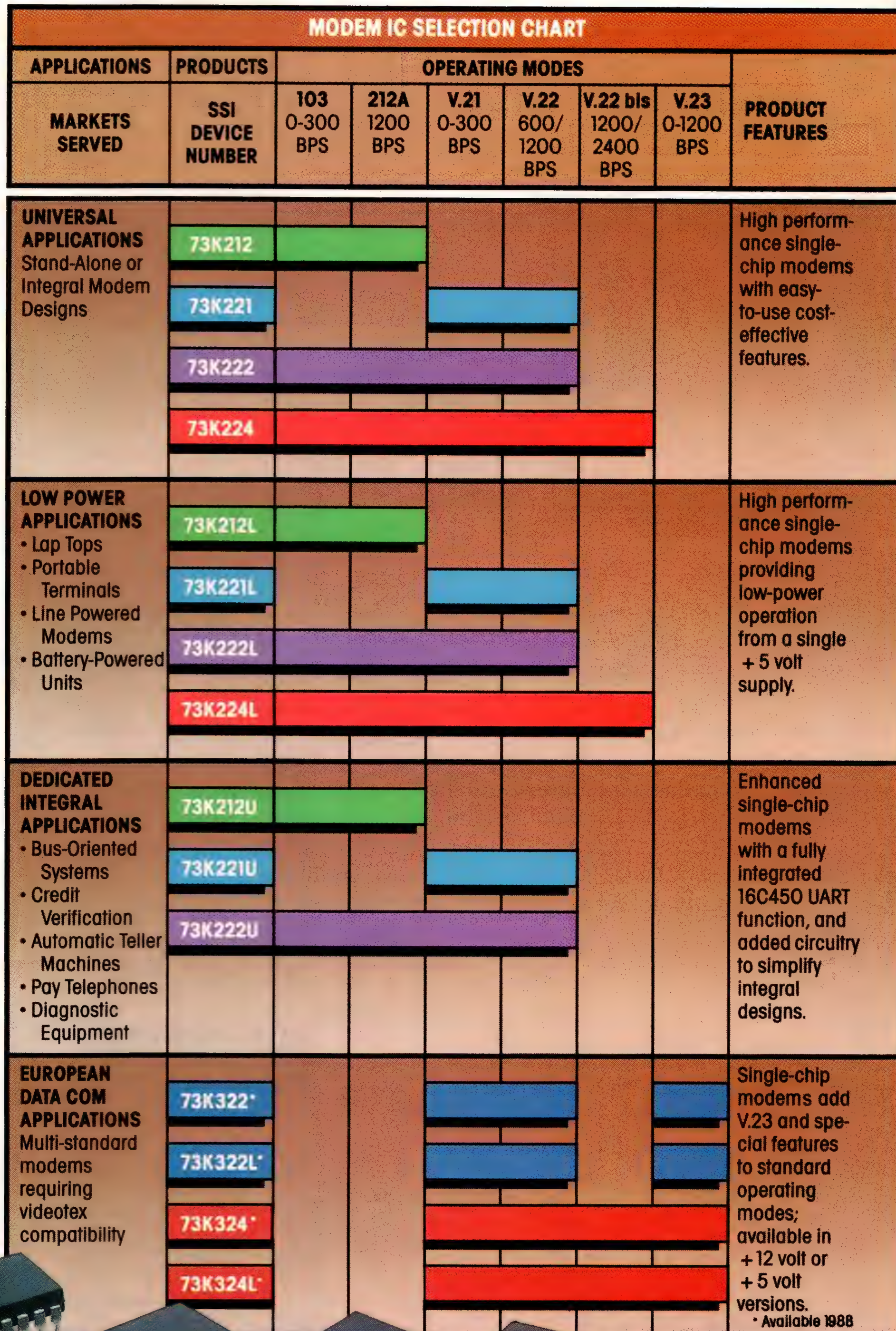

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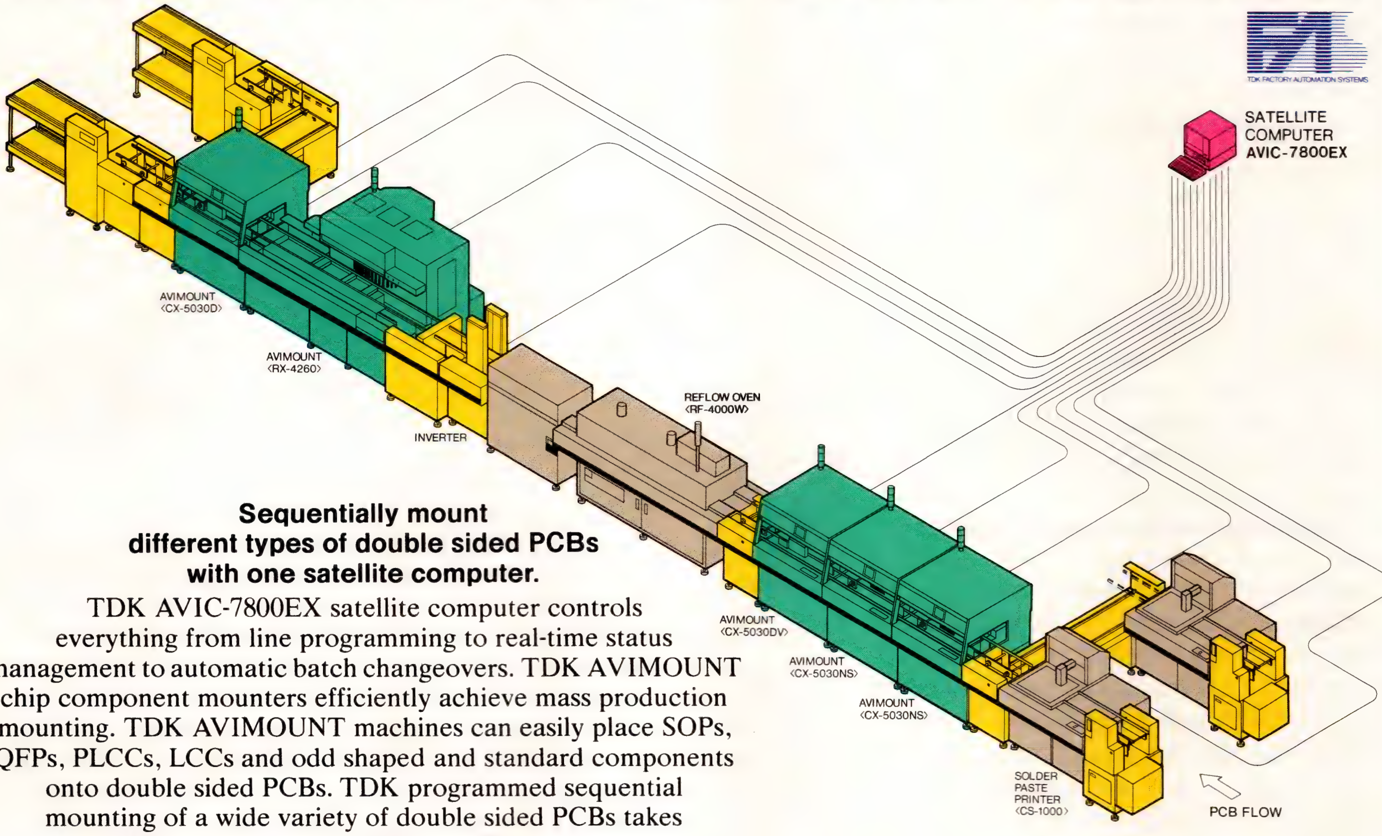

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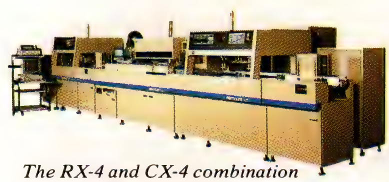

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High-speed buffers help solve problems in circuit applications

Although high-speed, unity-gain buffer amplifiers have been available for several years, recent versions serve a wider variety of applications. The high speed of today's devices makes them attractive for use in S/H circuits, active filters, and video switches.

Bob Underwood, *Maxim Integrated Products*

Modern high-speed buffer amplifiers solve a variety of circuit problems, but the design tradeoffs that increase their speed can also degrade their dc performance. Fortunately, these effects are predictable and, in most applications, correctable.

Although most of the circuits that follow will operate properly if you substitute an equivalent device, you must first check each device's specifications—particularly its input resistance, output-drive capability, and supply-voltage requirement. In some cases, the choice of a particular device can affect your circuit's performance. In other cases, you may need to adjust circuit values to optimize the buffer's performance. When your designs call for buffer amplifiers, consider one of the more popular devices, such as the LH0033, LH0063, and BB3553 (see **Table 1**). Several pin-compatible and improved versions of the devices are now also available.

Because a buffer amplifier's input provides a high-impedance load, designers often use such amplifiers in transducer or low-signal-level applications. However, the buffer amplifier isn't a lightweight contender. Its output can drive a moderate to heavy load. If a buffer amplifier's input is dc coupled to a transducer or other signal source, then the buffer's input impedance is simply its resistance and capacitance as specified in its data sheet. Note, though, that the relationship between input bias current and input voltage is nonlinear in many buffers. So, you must make certain that the input-resistance values for a particular buffer amplifier are specified over the input-voltage ranges you'll use for it.

Several common situations require ac coupling at the

TABLE 1—REPRESENTATIVE BUFFER AMPLIFIERS

TYPE	MANUFACTURERS
BB3553	BURR-BROWN, MAXIM
EL2003	ELANTEC
HA5002	HARRIS
HA5033	HARRIS
HOS100	ANALOG DEVICES
LH0002	ELANTEC, NATIONAL
LH0033	ANALOG DEVICES, ELANTEC, MAXIM, NATIONAL
LH0063	MAXIM, NATIONAL
LM110	NATIONAL
LT1010	LINEAR TECHNOLOGY CORP
MAX460	MAXIM
OPA633	BURR-BROWN

Buffer amplifiers provide high input impedance and drive a moderate to heavy output load.

buffer's input: Such coupling is necessary when you operate the buffer from a single power supply, when you remove a dc level from the signal, and when you use transducers that don't furnish a dc signal. In these applications, you must connect a resistor between a dc supply and the buffer's input to supply the buffer's bias current. The resistor's value must be low enough to supply the buffer's input current without causing too much voltage drop. However, the resistor's value must also be high enough so that it doesn't load the transducer excessively. In either event, the dc-bias resistor usually dominates the buffer circuit's input resistance. Remember that when a transducer supplies a capacitive output, the buffer amplifier's input resistance limits the low-frequency response of the circuit.

A typical bootstrap circuit (**Fig 1**) provides an input impedance that exceeds the impedance of any of the circuit components. Although the MAX460 buffer operates from a single supply in this circuit, you can reconfigure the circuit to operate with conventional split power supplies. During operation, an ac signal passes through the input capacitor, appears at the input to the buffer, and is available at the buffer's output at nearly unity gain. The output signal is capacitively coupled back to the low end of the input resistor network, which results in an effective multiplication of the resistive value. The circuit's total input capacitance arises from several sources; the intrinsic buffer-input capacitance, stray capacitances within the circuit layout, and the dc bias resistor's capacitance. You can reduce all of these capacitances by judiciously using shields and guards.

The circuit of **Fig 1** was tested while operating from a source resistance of 1 MΩ in series with a 10-pF capacitor. Under these conditions, the measured low-frequency −3-dB point was 3.3 Hz, and the low-frequency input circuit's time constant was 48 msec. These values are equivalent to those you would measure for a 4800-MΩ shunt-input resistor and a 10-pF series capacitor. The high-frequency input time constant was 0.7 μsec and had a −3-dB point of 227 kHz, which equates to an input capacitance of 0.7 pF when you use the 1-MΩ series resistor. An input capacitance this small might be difficult to reproduce because it depends greatly on the configuration of the driven guards connected to the output. Also, the buffer amplifier's case was connected to the output, and the test circuit had no special mechanical support for the input node. However, it should be possible to obtain a 1- or 2-pF input capacitance by connecting guards to the output and by supplying Teflon standoffs for mechanical support.

Buffer amplifiers can also serve in sample-and-hold (S/H) amplifier applications. In most such circuits, you need a buffer amplifier so that the output load does not discharge the hold capacitor (**Fig 2**). You can consider almost any of the available buffer amplifiers for this application, but in terms of low input current, some are better than others. For example, the MAX460 was designed for this type of application; its input current is low and is virtually independent of the input voltage.

In an S/H application, the switch's characteristics are critical. Ideally, the switch should have no offset voltage, low or zero on-resistance, and low or zero leakage, both across its contacts and from its output contact to its control terminal. Any capacitance between the switch's control terminal and its output couples a charge from the control input to the charge-storage capacitor. As a result, switching from the sample mode to the hold mode adds an error voltage to the analog signal being held by the circuit. It's sometimes possible to calibrate an S/H circuit to account for such a constant

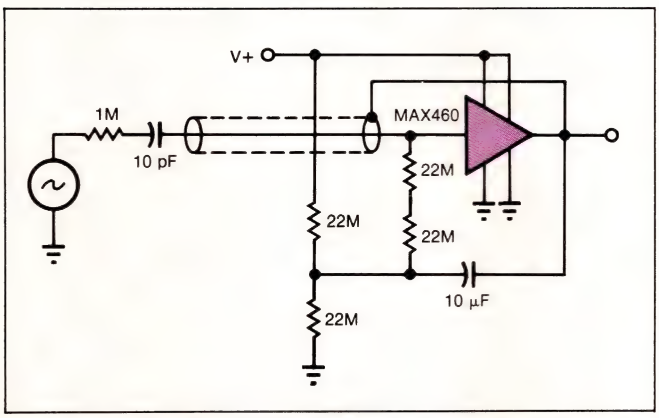


Fig 1—This basic buffer circuit employs bootstrapping techniques *that provide an ultrahigh-impedance input for a transducer signal. The MAX460 buffer amplifier operates from a single power supply, but you can reconfigure the circuit to operate from a dual supply.*

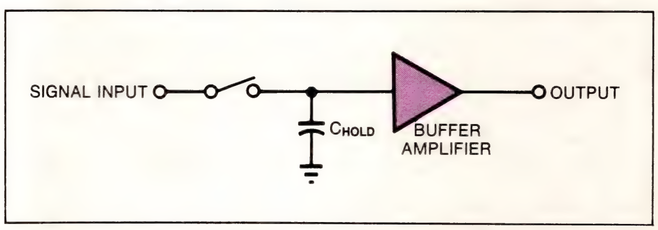


Fig 2—This basic sample-and-hold circuit *charges a capacitor by passing an analog signal through a switch. Opening the switch holds the charge on the capacitor. The buffer amplifier's high-impedance input prevents the output load from discharging the capacitor.*

error, but often the charge injection is not constant; it varies with input voltage, temperature, or time. Thus, it's best to minimize any charge-injection errors by minimizing the switch's parasitic capacitances.

The SD5000 DMOS switch IC is a good choice for S/H applications: When the chip's switch is closed, it has no offset voltage. The switch's capacitances are reasonably low, and it offers tolerably low on-resistance and leakage current. Because the SD5000 device provides four independent switches, you can connect two switches in parallel to further lower the circuit's on-resistance. You can also use the two remaining switches as a dummy capacitor, which lets you balance any charge that might be injected by the active switch section. Such a technique can result in nearly a tenfold reduction in the injected charge, without any need for manual circuit adjustments. However, if you require even better performance, you can add manually adjustable components to the circuit.

The hold capacitor is the heart of all S/H circuits. As such, it must have a high breakdown voltage and low leakage current, and it should be made of a material that has a low dielectric absorption. Typically, polycarbonate, polystyrene, and polypropylene exhibit good dielectric characteristics, but glass, mica, and most ceramics do not.

Some S/H circuits—particularly those that employ low-charge-injection techniques—may require only a switch, a hold capacitor, and an output buffer. More often, however, the circuit demands an input buffer amplifier, too. Without an input amplifier, the signal source must supply the hold capacitor's charging current.

Build high-speed S/H circuits

A realistic S/H circuit **(Fig 3)** contains an input buffer amplifier (IC_1), an output buffer amplifier (IC_2), and a DMOS FET switch. A voltage-level translator circuit made up of transistors Q_1 through Q_4 converts the ECL-compatible input signals to a voltage (referenced to the analog signal voltage) that drives the DMOS FET switches. The circuit employs Q_1 and Q_2 to form a differential amplifier that accommodates the balanced incoming ECL signals (Q and $\overline{Q}$). The four transistors are high-speed types that have a gain-bandwidth product (F_T) in the gigahertz range. Transistors Q_1 and Q_2 must have a breakdown-voltage rating that at least equals the circuit's positive supply voltage plus the ECL common-mode voltage of −2V. In this circuit, a breakdown-voltage rating of 17V is adequate. Likewise, transistors Q_3 and Q_4 require breakdown voltages of at least 25V to allow for a −10V analog input.

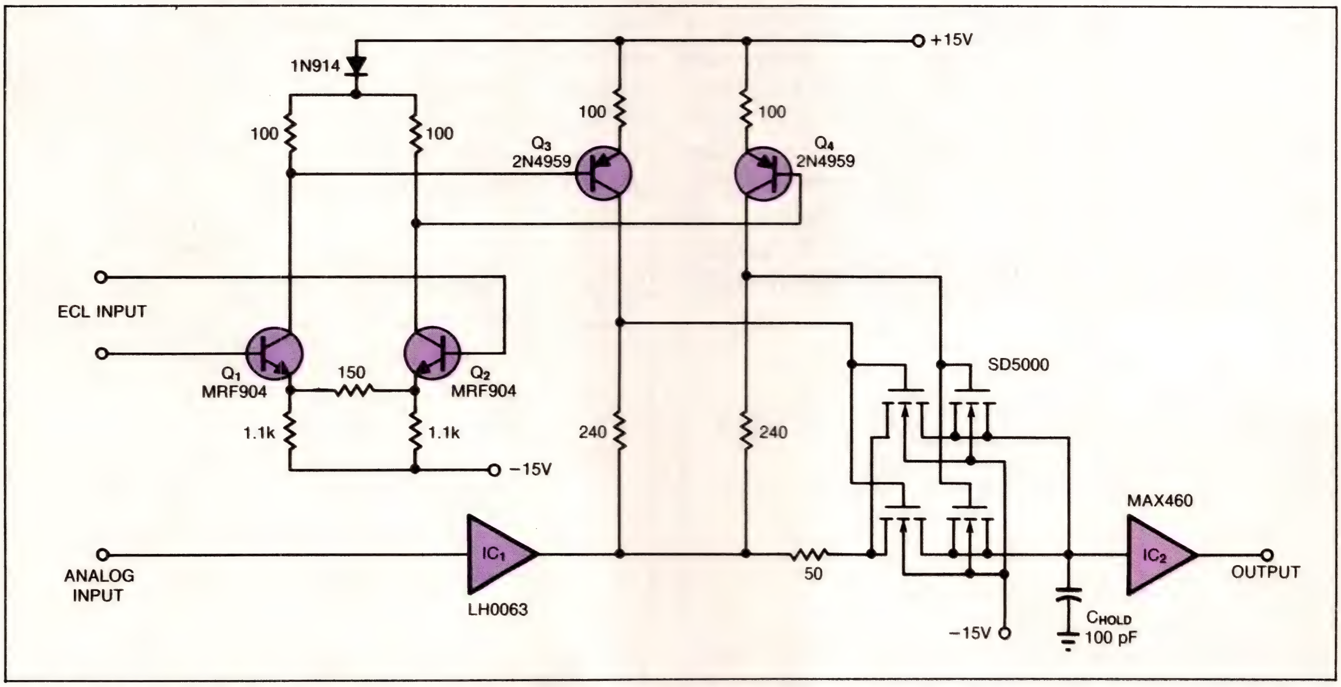


***Fig 3—This high-speed S/H circuit** includes an input buffer, a DMOS switch, and an output buffer. High-frequency transistors Q_1, Q_2, Q_3, and Q_4 form a level translator that converts the ECL input signal into a voltage that can drive the switch's gates.*

The bootstrap technique creates an input impedance value that exceeds the impedance of the individual circuit components.

Because the level-translator circuit is inherently nonsaturating, the transistor's storage time is not a critical consideration. In fact, you can use high F_T RF transistors for all four devices. The collector loads of Q_3 and Q_4 are returned to the analog input voltage (buffered by IC_1), which keeps the analog and digital circuits completely balanced. Note that the circuit also provides a set of dummy switches. The circuit's balanced nature is the secret of its excellent hold-step performance. The measured charge injection of the circuit in breadboard fashion—and without any circuit adjustments—was 100 mV into a 33-pF hold capacitor, which represents a 0.165 pJ charge injection. A stray capacitance of 1 pF between the FET switch's gate and the hold capacitor would just about account for such a small hold step.

The breadboarded circuit was adjusted, with a short piece of stiff wire, to add about 1 pF of capacitance between the compensating gate and the hold capacitor. By moving the wire, you can adjust the circuit to put out 0V for a 0V analog input. When properly adjusted, the circuit gave an output error of only a few millivolts over the S/H circuit's entire ±10V analog-input range. Also, replacing any of the semiconductor components had no effect on the hold step. In short, you don't need closely matched components for this type of S/H circuit.

Construct active filters, too

You can also use buffer amplifiers to build filters of various configurations. Although lowpass filters and other filter types do have their uses, notch and highpass filters have the most practical applications. For example, you can use a 2-pole highpass filter to remove low-frequency signal components with little effect on signals that occur above the filter's cutoff frequency. As **Fig 4** shows, the basic filter circuit exhibits a damping factor of 1 and a cutoff frequency of 1 kHz. The damping factor is controlled by the ratio of R_1 to R_2. You can scale the filter's frequency by changing the capacitor values, but both values must be equal.

Often referred to as a bridged-tee notch filter, the circuit shown in **Fig 5** consists of a series resistance and a shunt capacitance, bridged by a series-capacitance and a shunt-resistance section. In this filter circuit, dc levels pass through the series resistors, while at frequencies well above the notch the resistors have no effect. Instead, the high-frequency signals pass through the series capacitors and go on through the buffer to the output. Only the accuracy of the components, the loading by the output buffer amplifier, and any stray capacitance incurred in the filter's construction limit the maximum signal rejection at the notch frequency.

The readily available component values shown in **Fig 5** create a notch filter centered at 60 Hz. If you use 1%-tolerance resistors and 2.5%-tolerance capacitors, adjust the notch by trimming R_3 for a null at 60 Hz. When properly adjusted, the notch is deeper than −60 dB at 60 Hz, and the notch width is about 2.5 Hz at −40 dB.

Filters aren't the only signal-processing application for buffer amplifiers. You can use buffer amplifiers in video-signal switches, too. For example, an IH5352 chip lets you construct a moderate-performance 2-input, 2-output video crosspoint switch. But because the IH5352 has high shunt capacitance and high series resistance, problems can arise when you use the chip directly in high-performance video circuits. Luckily, you can alleviate the problems by buffering the video switch's input and output signals.

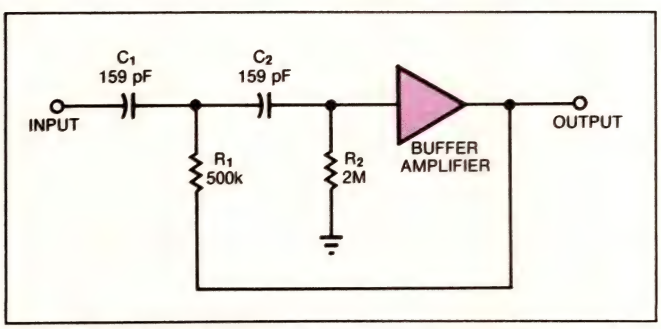


__Fig 4—This basic 2-pole, highpass filter__ requires only a buffer amplifier and a few passive components. This circuit has a cutoff frequency of 1 kHz and a damping factor of one. The damping factor is set by the ratio of R_1 to R_2.

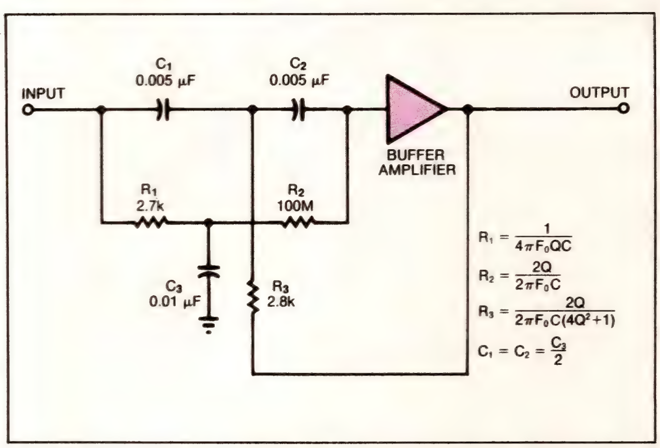


__Fig 5—This bridged-tee notch filter__ produces a −60 dB notch at 60 Hz. The buffer amplifier provides the necessary high input impedance.

In the circuit shown in **Fig 6**, the two video inputs feed through input buffer amplifiers (IC_1 and IC_2) to generate low-impedance signals that drive the analog-switch IC. Depending upon the input signal's source, each buffer-amplifier input may require a termination resistor. The termination resistors keep the amplifiers from saturating if an input is unconnected or is fed with an ac-coupled signal. A disconnected channel, for example, could turn on the switches and feed a high dc voltage to the output buffers. Because of the buffer amplifiers' input capacitances, a slight impedance mismatch may exist at the input terminals, but it usually doesn't limit the circuit's performance.

If you can accept a 6-dB loss through the switches, you can eliminate the output buffer amplifiers (IC_3 and IC_4). Such a loss might be tolerable, but switch-resistance values can vary considerably, which leads to an uncertainty about the actual signal loss. The output buffer amplifiers solve the loss-uncertainty problem and at the same time provide a low-impedance output that drives transmission lines either directly or through an accurate termination resistor. When operating from a ±15V power supply, the video circuit **(Fig 6)** handles a ±10V signal.

Restore dc levels

You can also use buffer amplifiers to restore the dc portion of a video signal. For example, because of the inherent ac coupling used in baseband video circuits, you frequently encounter video signals that have indeterminate dc sync levels. Because composite-video signals include dc sync pulses and ac picture information, the brightness of the scene influences the voltage level of the sync pulses as the complete video signal passes through an ac-coupled circuit. You can use several methods to re-reference the signal to ground.

The classic dc-restorer circuit **(Fig 7a)** passes the ac input signal through a capacitor (C_1) to a diode-resistor shunt (D_1-R_1). The time constant for R_1 and C_1 must be long enough to pass the lowest frequency component of interest in the input waveform, yet short enough to recover quickly from a fast change in the input waveform. However, the diode's forward-voltage drop produces a signal that is dc-restored to −0.7V, not to ground. By adding a resistor and an additional diode **(Fig 7b)** you can restore the video signal's sync pulse to

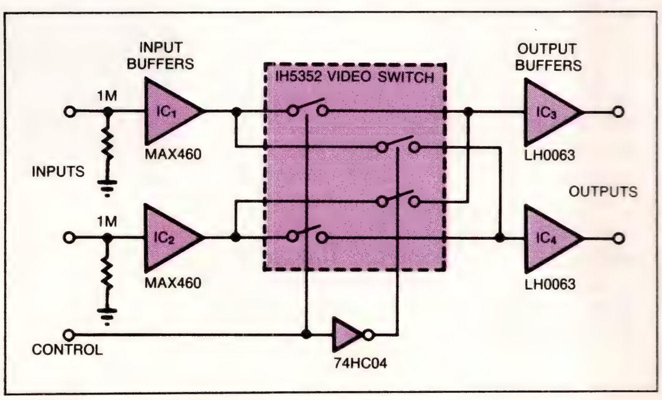


__Fig 6—Four buffer amplifiers help overcome__ the inherent limitations of a video-switch IC. The input buffers produce low-impedance signals that drive the analog switches, while the output buffers eliminate gain variations that result from unmatched switch resistances.

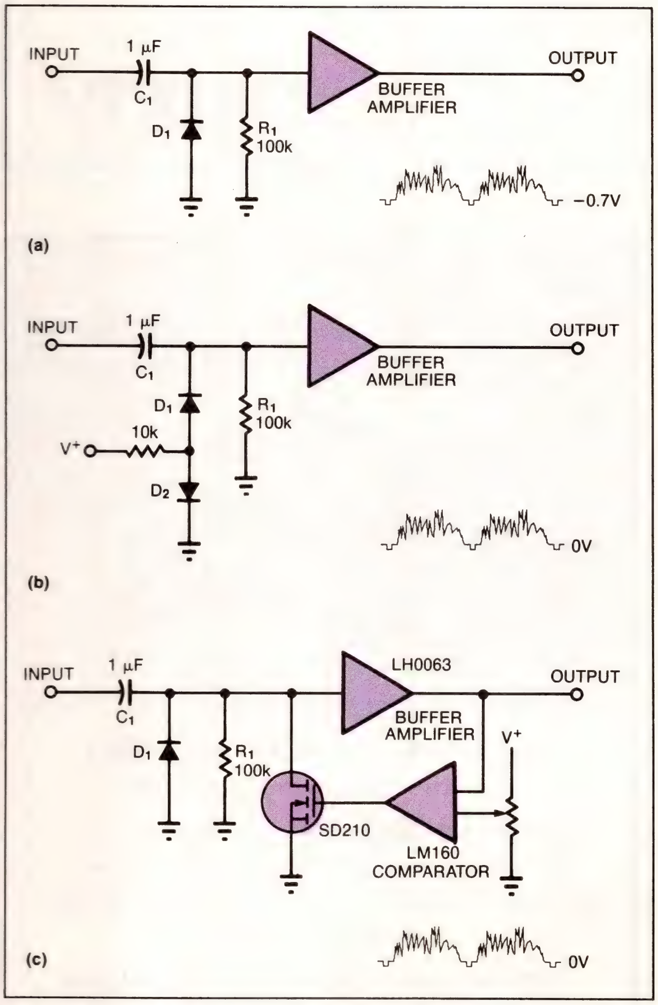
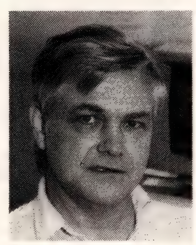


__Fig 7—Baseband video systems frequently require restoration.__ The basic circuit __(a)__ couples an input signal through a capacitor to a diode-resistor combination that restores the dc reference to −0.7V. Adding a resistor and a diode __(b)__ lets the circuit restore the sync pulse to 0V. You can further refine the circuit by adding an analog switch and a comparator __(c)__.

0V. The added diode (D_2) produces a 0.7V output that should exactly cancel the forward voltage of D_1. The added diode also cancels D_1's −2 mV/°C temperature coefficient. In practice, the current in D_1 depends on the input signal's characteristics, so an exact cancellation of forward-voltage drops and temperature coefficients is difficult to achieve. You won't be able to match the diodes' voltages to better than several tens of millivolts. The circuits shown are suitable for positive signals, but they can process negative-going signals if you reverse the polarity of the diodes.

A more sophisticated approach **(Fig 7c)** requires you to add an analog switch and a comparator to the basic dc-restoration circuit. In the new circuit, you bias the comparator a few hundred millivolts above ground so that the comparator recovers the composite sync information, rejects the video part of the signal, and turns on the SD210 analog switch during sync time. The comparator's action puts a voltage on C_1 that equals the input signal's voltage during the previous sync pulse. In effect, the circuit subtracts the stored charge from the incoming waveform, which yields a 0V signal during the sync interval. Diode D_1 speeds the recovery from any fast change in the input signal's dc level. Without the diode, the comparator might force the analog switch to conduct during the complete video cycle or at least until R_1 could act to bring the buffer amplifier's input voltage back into range. **EDN**

Author's biography



Bob Underwood is a senior member of the technical staff for hybrid design at Maxim (Sunnyvale, CA); he has been with the company for four years. Prior to joining Maxim, he was employed by National Semiconductor. Bob has a BSEE and an MSEE from Washington University in St Louis, MO, and he is a member of the International Society for Hybrid Microelectronics (ISHM) and the American Radio Relay League (ARRL). In his spare time Bob enjoys classical music, photography, and amateur radio, in which he holds an Extra-class license.

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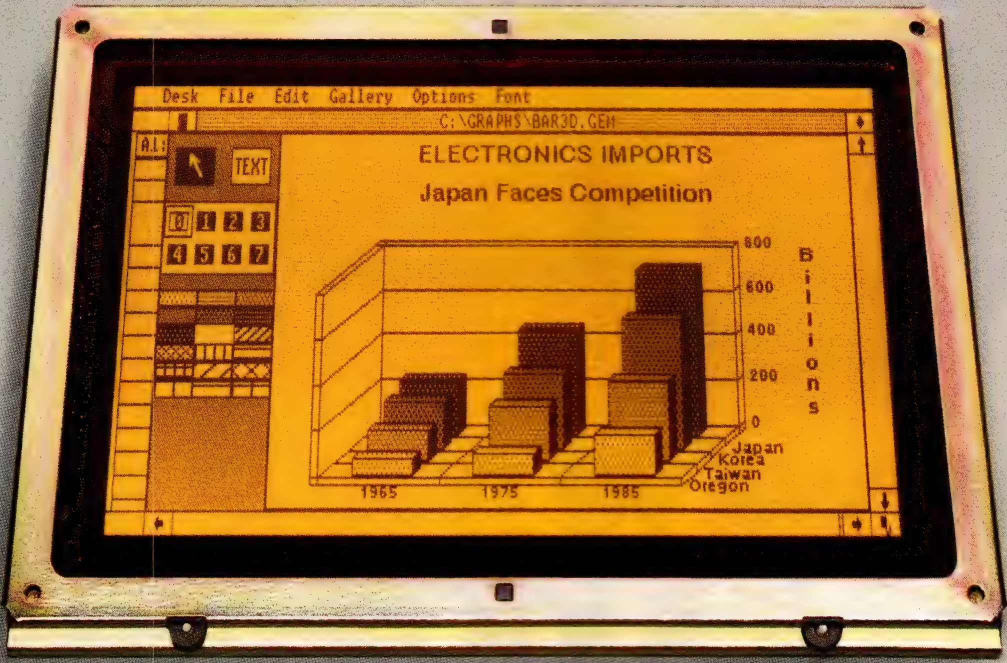

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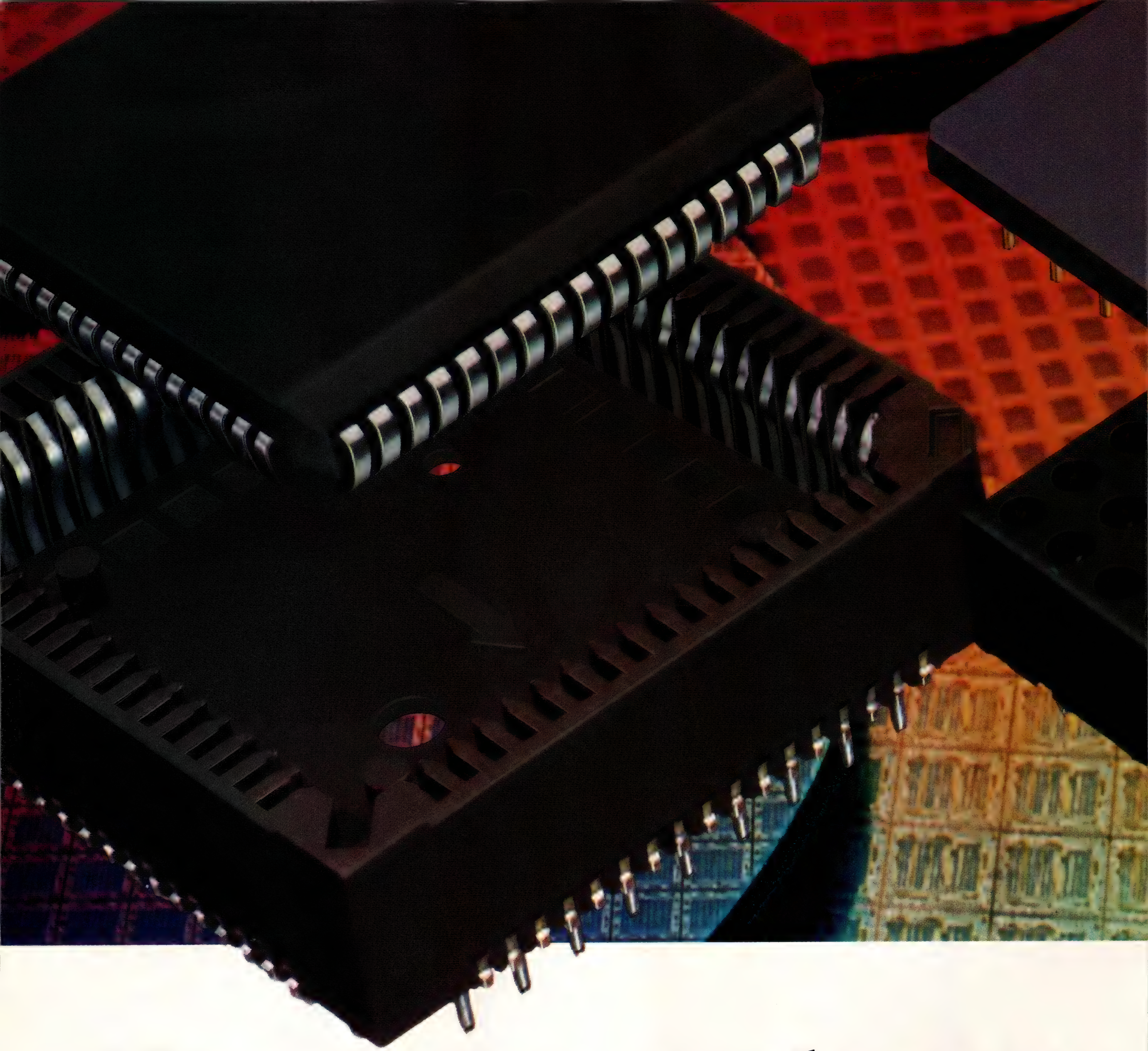

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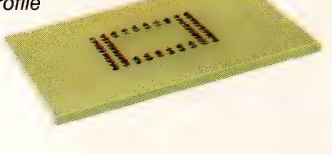

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Stable reference IC simplifies the design of analog systems

High-accuracy analog systems that previously required hybrid voltage references can now benefit from a precise and stable 1-chip reference IC. The device's tight specs and onboard features simplify the task of designing accurate, stable linear systems.

Bill Thompson, *Analog Devices Inc*

Initial accuracy, performance over a wide temperature range, and long-term stability are the traditional criteria for selecting a voltage reference. A reference is the cornerstone of any linear data-acquisition system, and its characteristics are reflected directly in the overall system specifications. A recent monolithic voltage-reference IC provides accuracy and stability previously obtainable only from hybrid references. By understanding the IC's specs, operating principles, and onboard features, (see **box,** "Inside the AD588 voltage reference") you can use the device in a variety of demanding, high-precision systems.

The AD588 combines ±1-mV accuracy and a ±1.5-ppm/°C temperature coefficient with a ±25-ppm/1000-hour stability spec. Accuracy and drift specifications such as these were previously impossible with monolithic voltage references. The circuits that follow take advantage of these specs and illustrate the impact that such specs have on your designs.

One of the simplest options you can exercise with a voltage reference is where to place the ground reference. By changing the location, you can produce either positive, negative, or split positive/negative output voltages. The circuit in **Fig 1a** produces a buffered 10V output from amplifier IC_{1C}. By connecting pin 13 of amplifier IC_{1D} to pin 11, 4, or 9 of the reference, you can obtain a 5V output, a second 10V output, or a buffered ground pin (respectively).

On the other hand, if you use the center tap of the reference's internal resistor string, you'll obtain both positive and negative outputs from the circuit **(Fig 1b).** This circuit provides ±5V tracking supplies. The key to obtaining negative output voltages from these reference circuits is to use the V_{HIGH} input (pin 6) as the ground-sensing point. The circuit of **Fig 1c** uses this ground-sensing technique to produce a buffered −10V output from amplifier IC_{1D}.

Add a noise filter

If your applications require better noise performance than that obtainable from the circuits in **Fig 1,** you can attach an external capacitor to pin 7 of the voltage reference. This configuration adds a lowpass filter to the input of amplifier IC_{1A}. Without the external capacitor, the reference's 0.1- to 10-Hz noise voltage is 6 μV p-p, and the broadband noise voltage (in a 1-MHz bandwidth) is approximately 600 μV p-p. The input

As the cornerstone of any linear data-acquisition system, the reference's specifications are reflected directly in the overall system specifications.

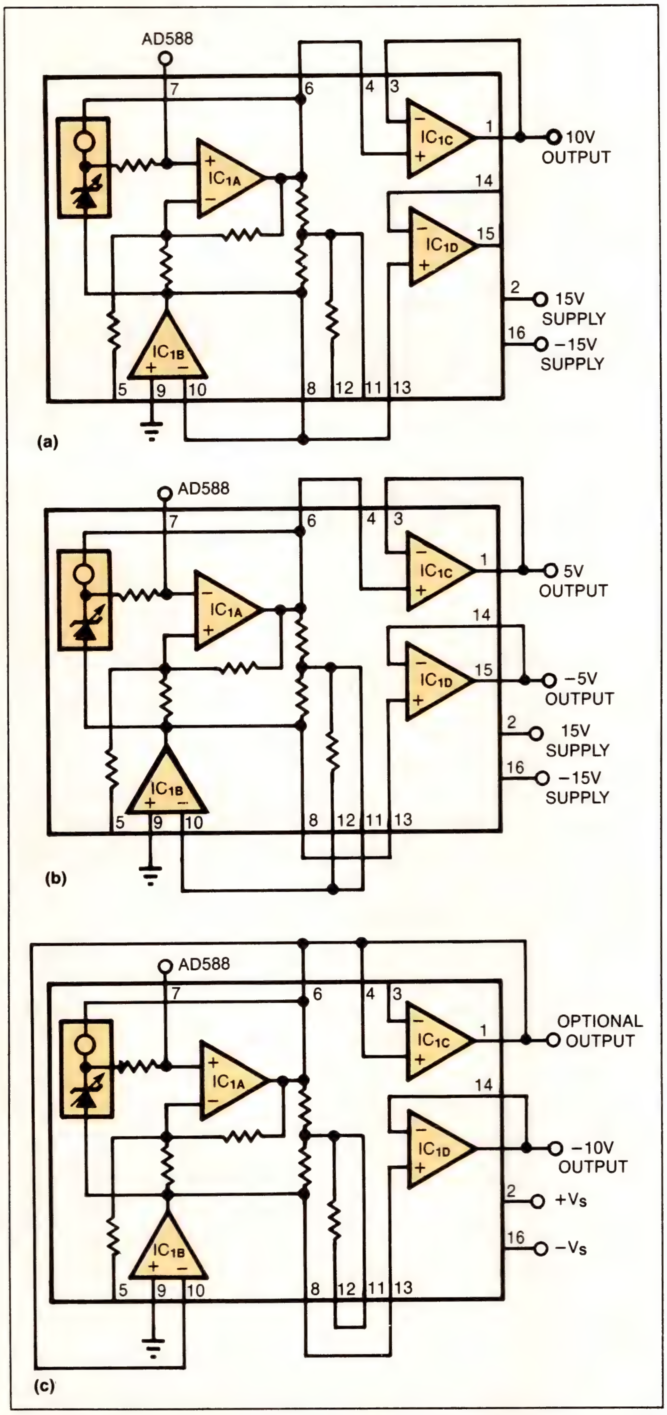

Fig 1—Judicious pin strapping yields a choice of outputs, *as is evident in these connection diagrams. The circuit in **a** produces a 10V output from buffer amplifier IC_{1C}. By connecting the noninverting input of amplifier IC_{1D} to the center tap of the reference's internal resistor string, you achieve both positive and negative outputs from the supply **(b)**. By using the V_{HIGH} input as the ground-sense point for the reference, you obtain a negative reference output **(c)**.*

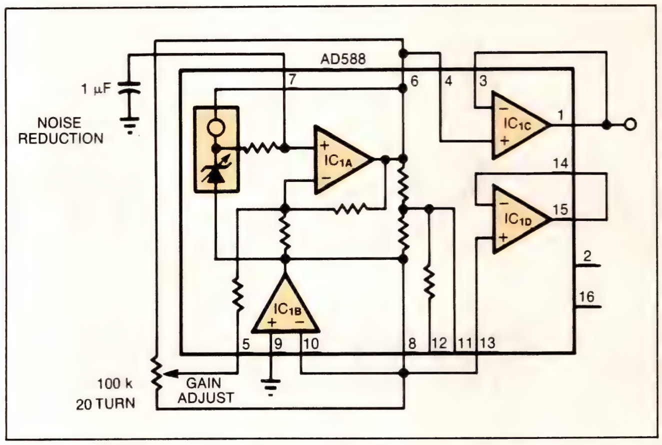

Fig 2—You can reduce the effects of noise *in your reference output by adding a filter capacitor to pin 7 of the reference. The gain-adjust potentiometer connected to the reference IC allows you to eliminate output-voltage errors.*

filter reduces the broadband noise contributed by the reference's zener cell. **Fig 2** includes a 1-µF capacitor connected to pin 7. The filter reduces the broadband noise voltage in this circuit from 600 to 200 µV p-p. You'll also notice the addition of a gain-adjust potentiometer in **Fig 2.** This potentiometer allows you to eliminate any output-voltage error in applications where a ±1-mV error is intolerable.

Use Kelvin sensing

If you're really concerned about accuracy in your application, you'll want to do more than filter the reference's input and use a null-adjustment potentiometer with the reference. To eliminate further possible sources of error, you can use Kelvin-sensing techniques (see **box,** "History of the Kelvin connection") to eliminate voltage-drop errors in branches of critical circuits. Current flowing through the parasitic resistances of the circuit connections themselves cause these errors.

As shown in **Fig 3a,** the load current from an ordinary voltage reference that lacks a sense terminal produces an error voltage that is proportional to the length and gauge of the connecting wire. The Kelvin connection, in this case, entails connecting an output amplifier as shown in **Fig 3b.** This Kelvin-sensing connection preserves the inherent accuracy of the voltage reference.

You can also modify the connection of **Fig 3b** to introduce a current-boost element into the force-sense loop **(Fig 3c).** This configuration provides increased load-current capability without any loss in accuracy. In the circuit in **Fig 3c,** the AD588, in conjunction with

Inside the AD588 voltage reference

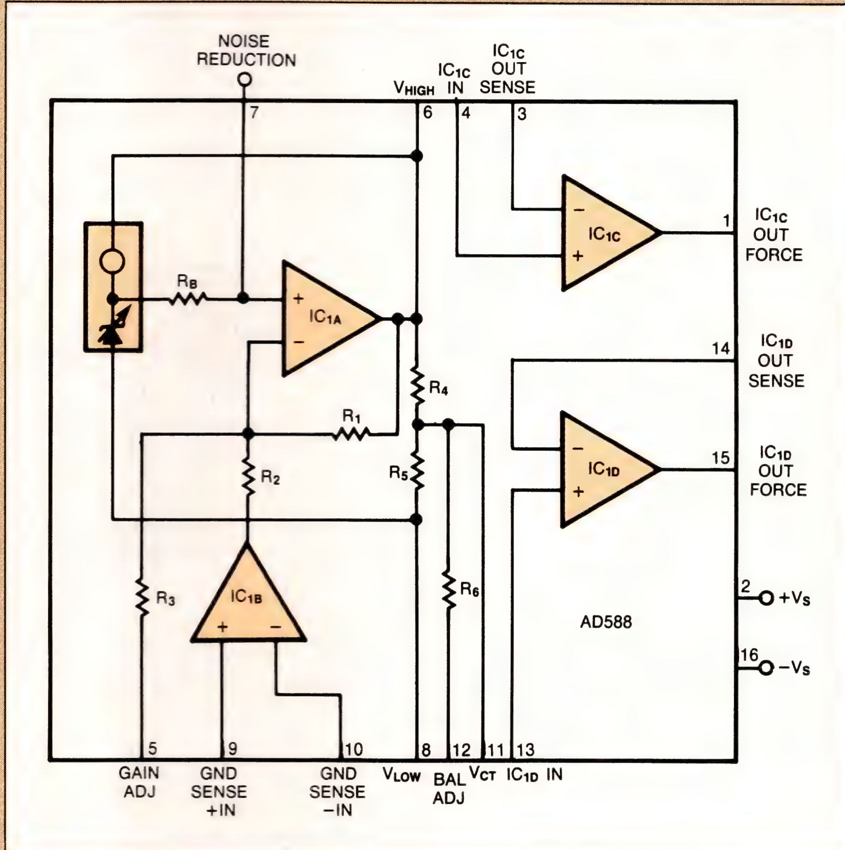

Fig A—A buried zener diode and a combination biasing and temperature-compensation network *constitute the principal elements of the AD588 voltage-reference IC. Multipoint temperature measurements provide the data for a laser trim that minimizes temperature drift. Pin strapping allows you to configure the reference for split or unipolar outputs.*

At the heart of the Analog Devices' AD588 **(Fig A)** are a buried zener diode and a combination biasing and temperature-compensation network. The zener diode is a subsurface device that offers superior stability over time and temperature, in comparison with a standard surface device.

The zener diode and its compensation network undergo testing at various temperatures. The test information is mapped into automatic test equipment, which then determines how to laser-trim each compensation network to minimize the reference's temperature-induced drift. Together, the zener diode and the compensation network produce a basic reference voltage of about 7V, having a temperature coefficient lower than ±1.5 ppm/°C.

Amplifier IC_{1A} and resistors R_1 and R_2 combine to boost the reference voltage to 10V. Resistor R_B provides compensation for the bias-current-induced offset-voltage errors at the inputs of IC_{1A}. R_B also forms a lowpass RC filter if you add an external capacitor to the Noise Reduction pin.

Resistor R_3, actually a modified H network, provides a limited gain-adjustment range. R_4 and R_5 split the output voltage into two equal parts that you can access through pin 11, the center-tap pin. Resistor R_6, also a modified H network, provides a limited balance-adjustment range.

Note that the 10V reference voltage "floats" on the output of amplifier IC_{1B}. This configuration endows the chip with a variety of output schemes. Because the high-impedance inputs of IC_{1B} are uncommitted, you can configure them (through pin strapping) to refer the reference voltage to either a local or remote ground, or to other voltages as well. With such flexibility, if you refer the reference voltage to either the center-tap pin or the V_{HIGH} pin, you obtain split ±5 or −10V outputs, respectively.

An additional feature of the AD588 is that amplifiers IC_{1C} and IC_{1D}, which can source or sink 10 mA, provide on-chip buffering capability. These op amps are internally compensated and protected against short circuits. They also have an input-protection scheme that allows them to recover rapidly from output-load transients.

To eliminate possible sources of errors, you can use Kelvin-sensing techniques to eliminate voltage-drop errors arising in branches of critical circuits.

two transistors, provides 28 mA of drive to the 350Ω bridge.

Digital-to-analog conversion is a discipline that requires particular attention to the accuracy of a voltage reference. The 14-bit multiplying D/A converter of **Fig** 4 operates in the bipolar mode, taking advantage of the AD588's configuration as a dual-output, tracking reference. If you insert jumper 1, the output voltages are ±10V. The 10V produced at pin 6 of the reference, buffered by amplifier IC_{1C}, connects to the V_{REF} input

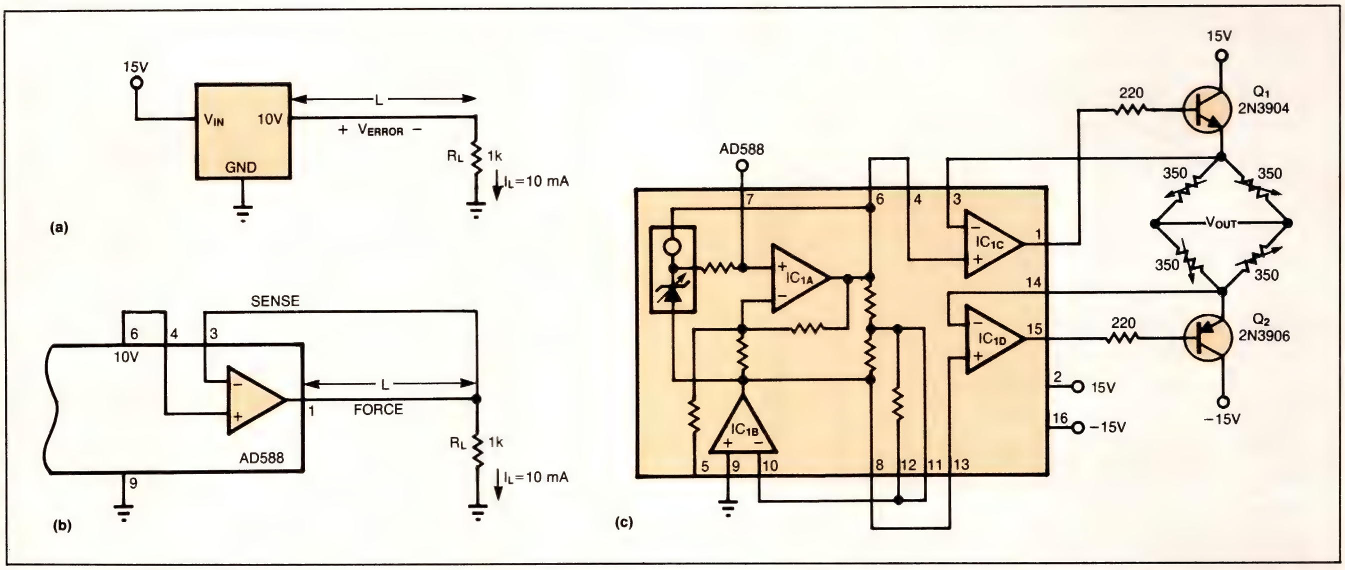

***Fig 3—The utility of the Kelvin, or force-sense, connection** is evident in this sequence of diagrams. In **a**, you can see the origin of the error voltage attributable to interconnection resistances; **b** demonstrates, in a generic fashion, how to circumvent this problem; and **c** illustrates the Kelvin connection in a resistor-bridge application.*

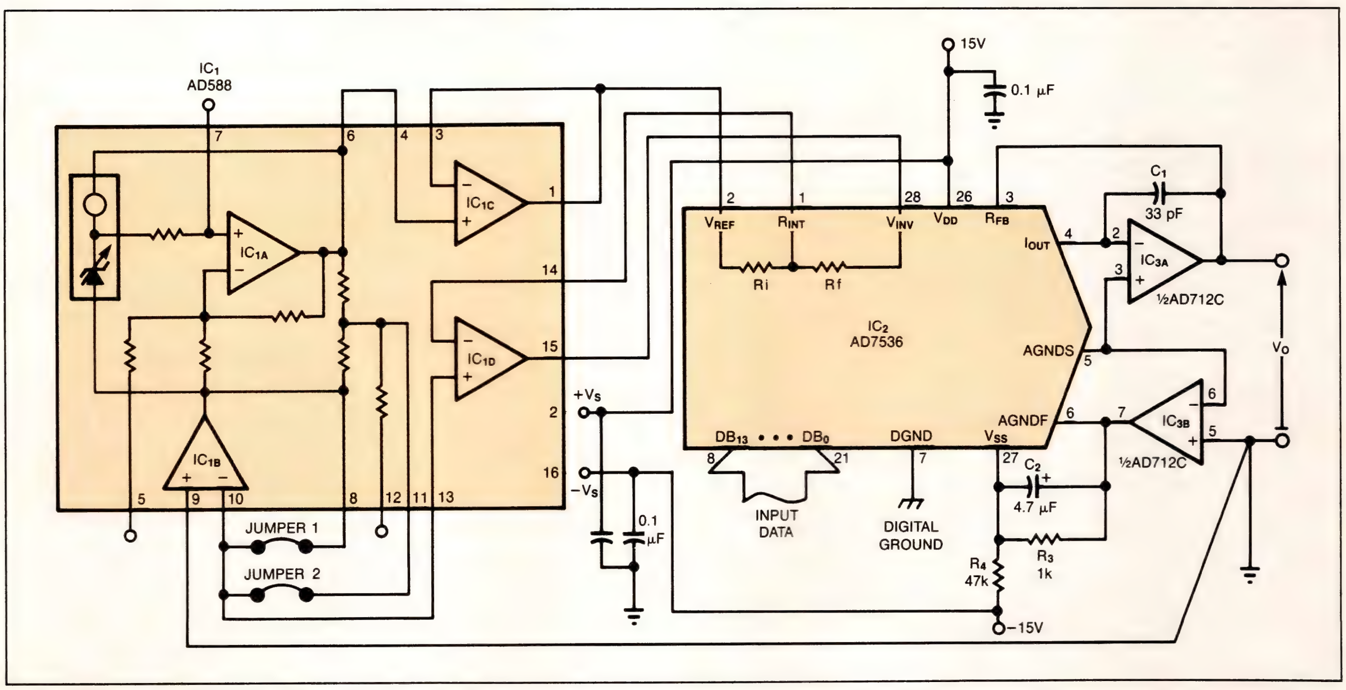

***Fig 4—In this high-resolution D/A-converter application,** the AD588 provides tracking voltages of opposite polarities to the AD7536 14-bit D/A converter. You can control the output range of the DAC by selecting jumper 1 or jumper 2 at the voltage reference.*

History of the Kelvin connection

Although the force-sense or Kelvin-connection technique is in wide use, most engineers aren't aware of the origin of the method. It is named for the author who first described a solution to the difficulties encountered in using the Wheatstone bridge to measure the small resistance of metal samples.

In a paper published in 1862 **(Ref 1),** William Thomson related a situation where the Wheatstone-bridge method, which was in common use at the time, did not yield reliable data because of the unknown resistance of the bridge itself. In **Fig A,** these connections are shown as small squares associated with question marks, indicating the unknown value of the connections' resistance.

In order to circumvent this measurement limitation, Thomson added another half-bridge to the basic Wheatstone bridge in **Fig Aa** and moved the galvanometer, as illustrated in **Fig Ab.** He then proved that, when the ratio of resistance between R_{SAMPLE} and $R_{STANDARD}$ matched the ratio N of each portion of the primary and secondary test conductors, the galvanometer would assume a null condition. Even more important, he showed that this relationship was true in spite of the unknown —albeit small—resistances of the soldered connections.

The basis for Thomson's proof was that if the resistances of the primary and secondary conductors were made large relative to the resistances of the unknown connections, then "... the error arising from such imperfections as they must present may be made as small as is required." In short, he realized that he could measure the voltages, using high resistances, without disturbing the voltages being measured.

In the applications in the accompanying article, the high input impedance of the op amps in the circuits provides the high resistance used to accomplish this measurement. The configuration in **Fig Ac** illustrates how Thomson might have taken advantage of the high input impedance of today's op amps to improve upon his sensing method.

You may wonder why this method of sensing is dubbed "Kelvin sensing" when William Thomson is the man who invented it. Thomson subsequently devised an absolute temperature scale and was given the title Lord Kelvin in 1892; the Kelvin-sensing technique and the Kelvin temperature scale are both attributable to William Thomson, Lord Kelvin.

Reference

1. Thomson, W, "On the Measurement of Electrical Resistance," *Philosophical Magazine*, Fourth Series, Vol 24, 1862.

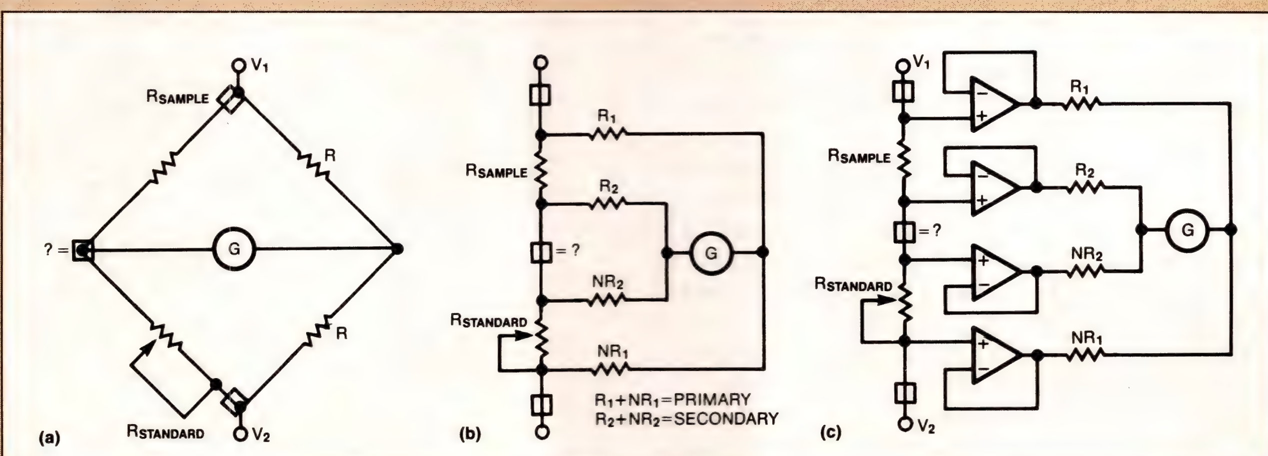

Fig A—The Wheatstone bridge (a) illustrates the dilemma Lord Kelvin encountered *while trying to measure the resistance of a small metal sample. The circuit in* ***b*** *is a schematic representation of his solution: He made the measurement dependent upon controllable ratios. The circuit in* ***c*** *includes voltage followers as high-impedance elements.*

In most reference stacks, the uppermost reference must supply its own load current, as well as the load and bias currents of all the other references in the stack.

pin of the D/A converter. If instead you use jumper 2, the output at pin 6 becomes 5V.

IC_{1D} is connected as an inverting amplifier that uses the on-chip resistors of the AD7536 as the inverting-input and feedback resistors. This configuration provides the converter with its required negative voltage (whether it's −5 or −10V depends on your selection of jumper 1 or 2). The D/A converter requires current-to-voltage converters and an active ground; IC_{3A} and IC_{3B} provide these functions. Resistors R_3 and R_4, along with capacitor C_2, provide a decoupled bias voltage for the output-leakage-reduction feature of the DAC.

If you use this reference for a higher-resolution D/A converter (for example, 16 bits), keep in mind the significance of the reference's noise and the role this noise plays in your system. For instance, in the foregoing 14-bit converter application, one LSB amounts to 600 μV (assuming a 10V full-scale range), whereas in a 16-bit D/A-converter application one LSB equals 150 μV. Use every technique available to you, including the Kelvin connection discussed earlier, to minimize noise voltages in these applications.

Sometimes you need to produce several precision output voltages for your system. Several schemes can satisfy this multiple-output requirement, but many of them suffer from load-interaction problems. The circuit of **Fig 5** produces multiple, precision outputs and exhibits no load interaction. The circuit uses three AD588s, stacked to produce ±15, ±10, and ±5V high-precision voltage outputs. Other schemes usually refer one output to a previous output; consequently, output-voltage changes arising from the loading of the first output are reflected in the succeeding voltage references. The circuit of **Fig 5,** however, buffers each output; thus, the loading effects upon each reference are isolated from all the other references.

In most reference stacks, the uppermost device must supply its own load current, as well as the load and bias currents to all the other devices in the stack. This arrangement limits the practical load-driving capabilities of these configurations. In the buffered arrangement of **Fig 5,** though, each reference supplies its own load and bias currents—and extends the practical load-driving and biasing capabilities of each reference.

Another circuit that makes use of a high-precision voltage reference is a high-accuracy current source. The AD588 can operate as a current source with the addition of a single external resistor. One application that requires a very precise current source is the measurement of the sheet resistance of semiconductor

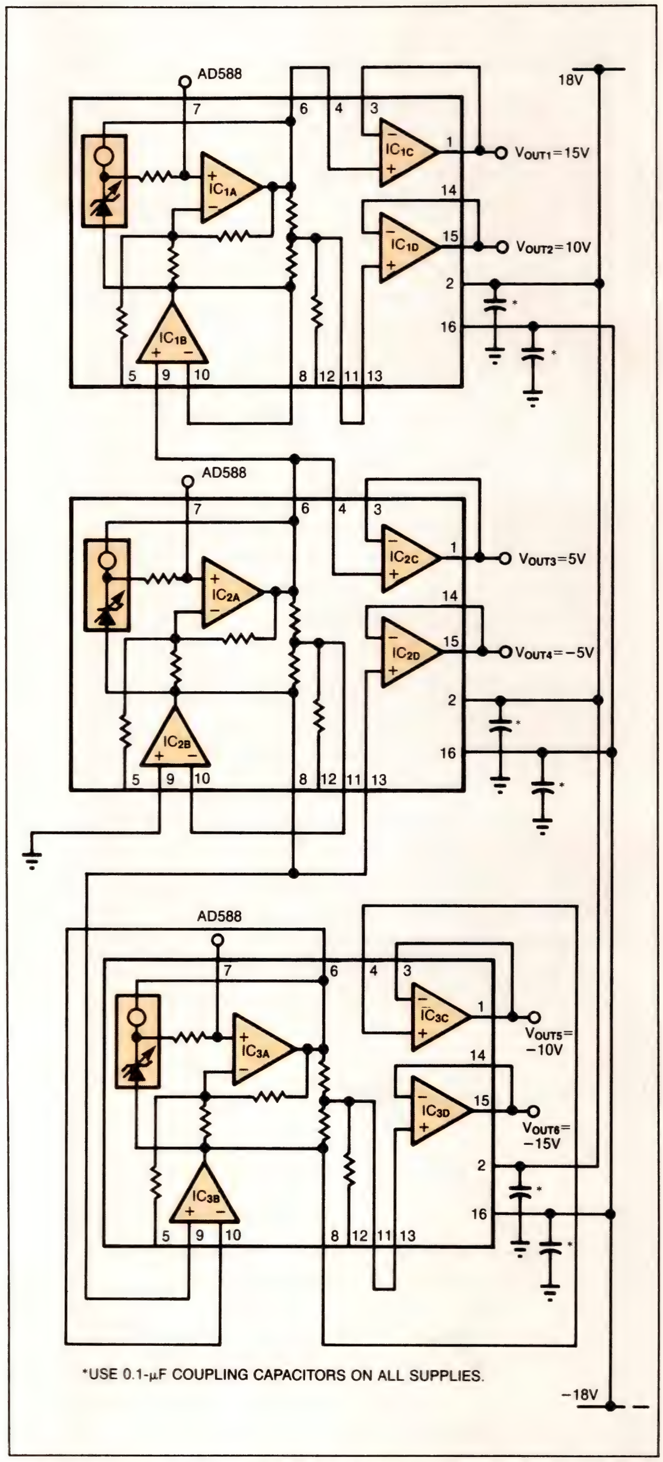

***Fig 5—Complete isolation among the three outputs** is the hallmark of this triple-stack reference. The effect of loading any of the three outputs has no influence on the other two. Moreover, the uppermost reference isn't required to supply the load and bias currents of the other references.*

test patterns through the use of a 4-point probe assembly. In the circuit of **Fig 6,** amplifier IC_{1C} buffers the output voltage supplied to one side of control resistor R_C. IC_{1B} senses the voltage drop across R_C, and the reference produces a 10V drop across R_C.

The high-impedance input of IC_{1B} draws essentially no input current, and therefore a current equal to $10V/R_C$ flows into probe 1. Amplifier IC_{1D} senses the voltage on probe 3, and compares it to system ground and the servo voltage on probe 4 to produce a virtual ground at probe 3. The current flowing through the sample produces a voltage between probes 2 and 3 that's proportional to the sheet resistance of the sample under test. A high-impedance digital voltmeter, connected between system ground and probe 2, measures this voltage. To calibrate the system, place a sample of known sheet resistance under the probe assembly and adjust the trim potentiometer.

In those cases where you need a precision current source that delivers as much as 10A, you can add a

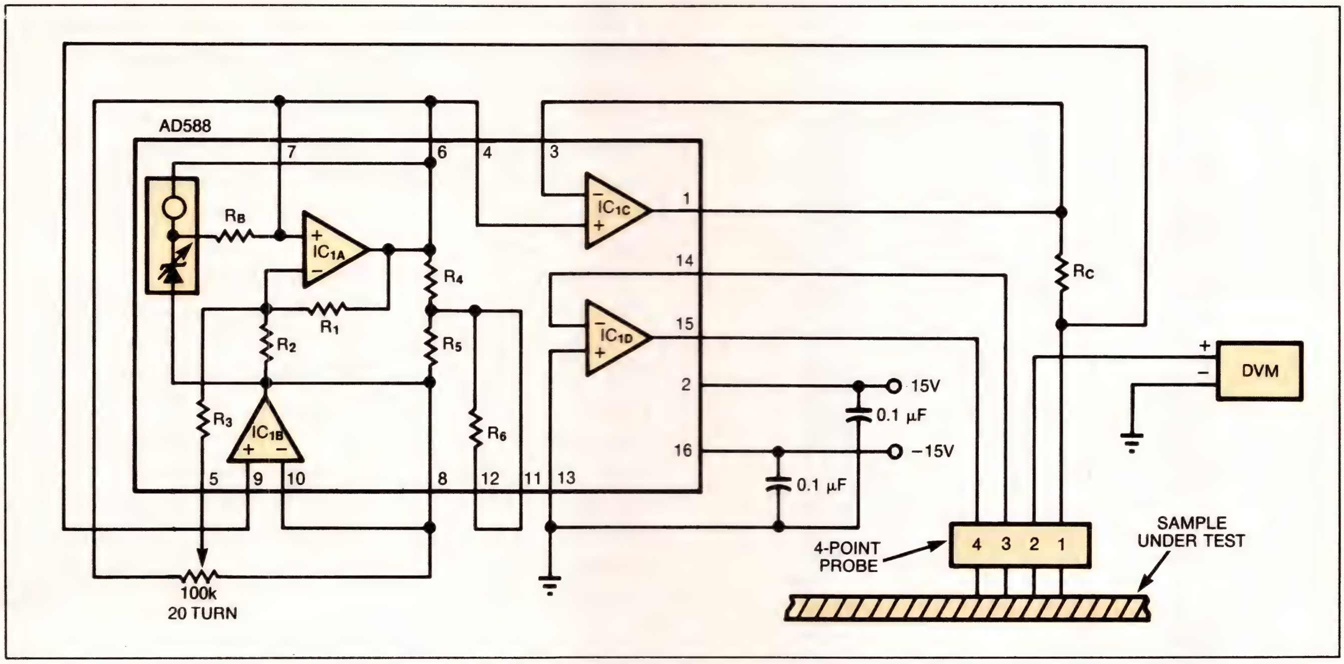

Fig 6—To make an accurate measurement of the sheet resistance of a material, *you need to supply a precision current source, such as the one shown here. The addition of a single external resistor configures the AD588 as an accurate current source.*

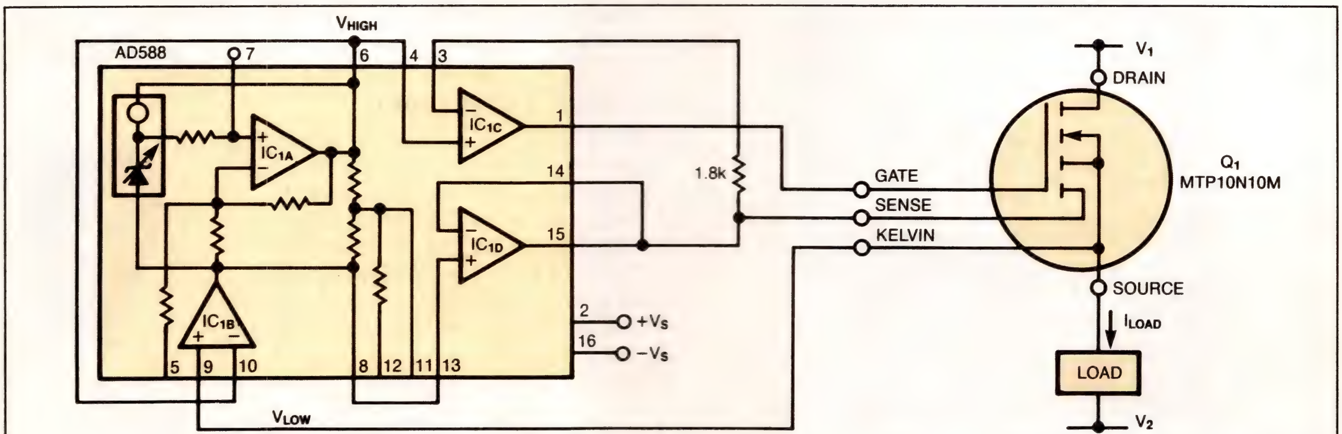

Fig 7—Adding an external current-sensing power MOSFET *allows you to configure a precision current source that can supply as much as 10A. The Sense FET uses Kelvin-sensing techniques to sense and control the load current.*

Motorola Sense FET (a power MOSFET having sense and Kelvin inputs) to the previous current-source circuits. The Sense FET's sense lead is connected internally to an area-ratioed source, which provides a sense current that's an accurate fraction of the load current. For the MT10N10M device in **Fig 7,** that fraction is $\frac{1}{1800}$. The Kelvin pin, internally connected to the source pin, allows for an accurate measurement of the voltage on the source terminal of the Sense FET.

In **Fig 7,** the AD588 produces 10V between pins V_{HIGH} and V_{LOW}. An internal amplifier, configured as a voltage follower, buffers V_{LOW}. V_{HIGH} is buffered by a second internal amplifier and Q_1. Connected in a source-follower configuration, Q_1 forces a current equal to $10V/R_C$ amperes through the external resistor; this current is also the sense current of the MOSFET. The load current of the MOSFET equals $1800(10/R_C)$ as long as the gate-to-sense voltage is equal to the gate-to-source voltage.

Differences in these voltages produce differences in the operating conditions of the sense and load transistors, thereby changing the 1800:1 ratio. The circuit of **Fig 7** eliminates these differences and therefore maintains the 1800:1 ratio. The Kelvin voltage connects to the noninverting input of a third internal amplifier. That amplifier adjusts V_{LOW} until V_{HIGH} exactly matches the Kelvin voltage. The MTP10N10M has a maximum drain-current rating of 10A; this maximum rating is the limiting factor in the scheme's overall current-sourcing capability. **EDN**

Reference

1. Schultz, W, "Sense-Cell MOSFET eliminates losses in source circuit," *EDN*, June 26, 1986, pg 169.

Author's biography

Bill Thompson is a product-marketing specialist at Analog Devices' Semiconductor Div in Wilmington, MA. He previously worked at Dionics Inc (Westbury, NY). Bill received his BSEE from Union College in Schenectady, NY. In his spare time, he enjoys sailing, skiing, and playing volleyball.

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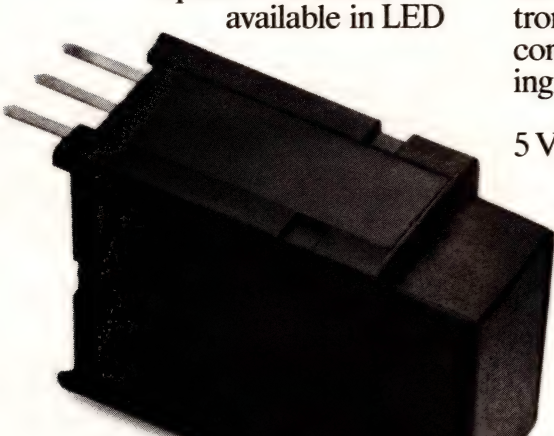

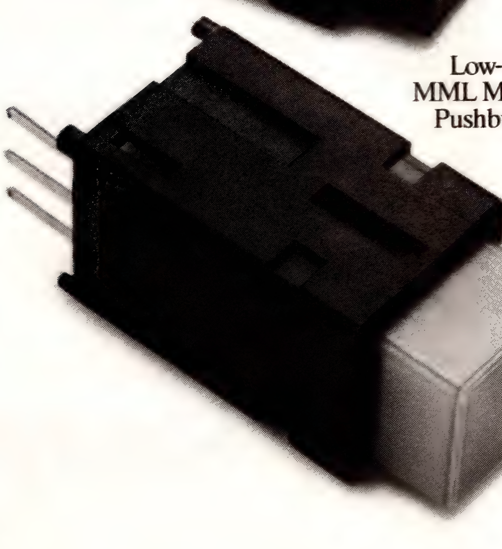

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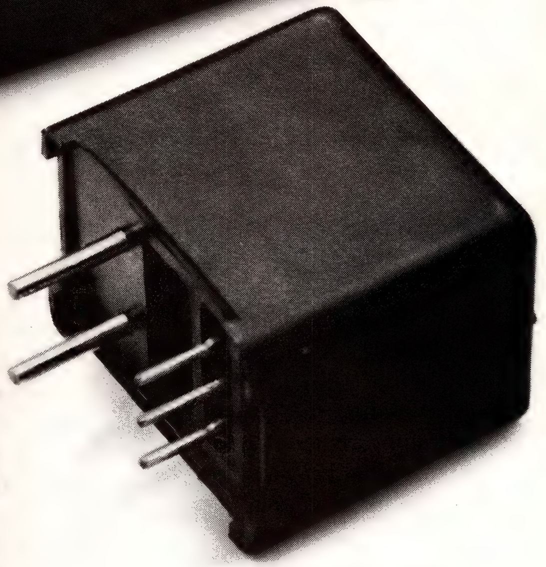

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Molded circuits require attention to new design techniques

Molded circuit boards offer designers creative opportunities that lead to new electronic products. But before you can take advantage of these molded circuits, you must consider new and demanding design guidelines. Fortunately, you can handle these additional considerations in a straightforward manner.

John Williams, *ICI Electronics*

Because molded circuits offer you the opportunity to expand your designs into an extra dimension, they provide an attractive alternative to flat pc boards for new designs. Molded-circuit-board features such as molded-in holes, connectors, standoffs, component mounts, and housings can reduce the cost of a product and simplify its assembly. But there's a price to pay; these new advantages and possibilities complicate the design process. As a result, you must make a number of tradeoffs when you switch from conventional 2-dimensional (2-D) pc boards to 3-dimensional (3-D) molded circuit boards.

By following the design guidelines addressed in this article, you'll be able to handle these tradeoffs in a straightforward manner. However, no single article can cover every aspect of molded-circuit-board design. Instead, this overview will help you understand the choices you must make as you design cost-effective 3-D or molded circuit boards.

The ability to run conductive traces in three dimensions opens many opportunities and offers you many choices in board design. Product features that would be impossible to incorporate into conventional 2-D pc boards are now at hand. For instance, circuits and conductor paths can become an integral part of a controller's housing, making it unnecessary to employ a separate pc board full of components.

The steps involved in designing the electronic portion of a molded circuit board are very similar—but not identical—to those you would use when designing a 2-D pc board. When you start your design, you'll find that its mechanical aspects often add new possibilities as well as new constraints. For example, your designs can include options such as new hole shapes, built-in tooling features, and special holding fixtures for surface-mount devices.

But before you delve into mechanical-design considerations, examine the electronic portion of your design. As with conventional pc boards, you can't run traces anywhere you wish on a 3-D circuit board. How you get those traces onto the board and where you place them become important parts of the design process.

When it comes to electronic-design considerations, molded circuit boards require new thinking. No longer can you simply specify trace widths and spacings and

Molded-circuit-board design rules specify minimum line widths and spaces.

expect your design to turn into a manufacturable product. For example, the additive plating process and the nature of the plastic substrate used for molded circuit boards change the design rules.

Although pc-board designers may take plated-through holes for granted, when you need plated-through holes in molded assemblies you must give them special consideration. In general, a molded board's cost decreases as the number of molded plated-through holes in it increases. However, there's a tradeoff between the number of holes and the assembly's structural strength. Increasing the number of holes in the molded assembly also increases the number of weld lines, and weld lines can be a source of structural weakness. The weld lines develop as the molding compound flows around the mold inserts that form holes in the assembly.

Design rules change

So, as you reduce the number of holes to strengthen an assembly, you also drive up its cost. In some cases, plated-through holes are necessary, but you can minimize their degrading effects by maximizing the space between them. Also, by carefully using surface-mount-technology (SMT) components you can reduce the number of holes and thus help reduce the number of weld lines in the assembly. The judicious use of SMT components can also help reduce the size of the molded unit.

Design problems go beyond the number of holes in a molded board to encompass hole-placement criteria as well. Whatever the number of holes, their proper placement can minimize molding problems. The farther apart the holes are, the easier it is for the plastic compound to flow into the mold cavities. Conversely, as you increase the number of holes in a design, filling the mold cavities becomes increasingly difficult. These molding considerations explain why it's very difficult to produce boards that are densely populated with through-hole components. As you can see, normal pc-board circuit-density calculations don't apply to molded boards.

Because the molded-circuit-board manufacturing process uses an additive plating process—rather than an etching process—to put metallic traces on the board's surface, pc artwork deserves special attention. For example, as the additive process plates metal on a circuit trace, the trace widens by 1.4 mils for each ounce of copper plated out. (A 1-oz copper plating is currently the maximum thickness available with the additive process.) As a result, there's a difference between the widths of traces on the molded assembly and the widths drawn on the artwork. This difference means that you must adjust your artwork to compensate for line spreading. So, if you want to create 15-mil spaces between 15-mil lines, for example, your artwork must incorporate 18-mil spaces between 12-mil lines. The preferred minimum line width and line spacing on molded circuit boards is 12 mils.

Vias and pads used to mount parts on a molded circuit board have their own special requirements. To begin, you must adjust pad sizes and the spaces between them to compensate for the trace widening that occurs during the plating process. Also, calculating the size of annular conductors for molded circuit boards is not quite as easy as it is for flat pc boards.

Different hole shapes can ease the assembly and

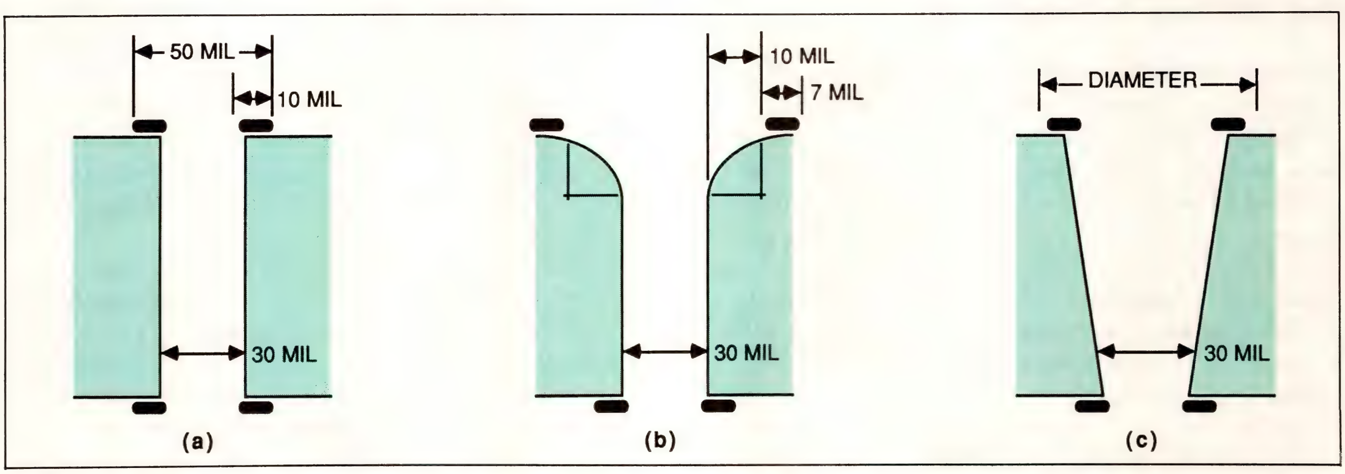

***Fig 1—Hole shapes dictate pad requirements** for molded circuit boards. Typical pad sizes for normal 30-mil holes **(a)** and 30-mil holes with a curved surface **(b)** are 50 and 64 mils, respectively. For a tapered hole **(c,)** pad sizes depend on the size of the hole at each board surface.*

manufacture of molded boards **(Fig 1)**. For a normal cylindrical hole **(a)**, the width of the annular copper ring—10 mils in this example—is simply measured from the outside edge of the hole. So, for a 30-mil-diameter hole with a 10-mil-wide ring, your pc-board layout requires at least a 50-mil-diameter pad. But when a molded pc-board design prescribes a curved entry or exit for a hole **(b)**, the layout requires a larger pad. You can use a slightly narrower annular ring (measured from the outside of the curve) in such cases. In the case of a 30-mil hole with a 10-mil-radius curved entry, you can specify a 64-mil-diameter pad. That pad diameter puts a 7-mil-wide annular ring around the outside of the hole.

If you choose to specify tapered holes **(c)**, you must remember to calculate pad diameter based on the diameter of the hole at the board's surface. For designs that require passing a conductor between the leads of an integrated circuit, the IC contact pads can't have a diameter greater than 64 mils. Molded circuit boards also restrict the hole sizes you can obtain. In short, you can't specify a hole of any diameter you wish, because the hole diameter depends on the thickness of the molded circuit board. You must maintain a maximum 3:1 aspect ratio between the board thickness and the hole diameter. Also, bear in mind that 30 mils is the smallest practical diameter for holes in molded circuit boards.

In molded circuit boards, ground planes and other areas completely enclosed by circuitry can cause problems that don't arise when you design 2-D pc boards. For example, true 3-D molded circuit boards can't contain areas that are completely enclosed by a ground plane or shield **(Fig 2b)**. The phototool can't accommodate such a shielded area. For the same reason, you can't run traces back on themselves to form an enclosed surface on the assembly. Your design can incorporate ground planes and solid-copper areas, but they can't enclose other circuit elements.

Broadening your horizons

When designing a board, you must develop a method that aligns or registers the circuit's artwork on the part. For a 2-D board, it's a simple matter of including targets on the film. Likewise, for molded circuit boards, you can mold film-registration targets right into the part.

Like traditional 2-D pc boards, molded circuit boards also require exposure to light for circuit-trace processing. So, as you design a 3-D circuit, remember that all circuit traces must be directly exposed to the light source during the image-processing steps. All conductor-placement considerations hinge on this point.

Several examples in **Fig 3** illustrate typical imaging considerations. View **a** shows a trace snaking around an overhanging part. Because the imaging light source

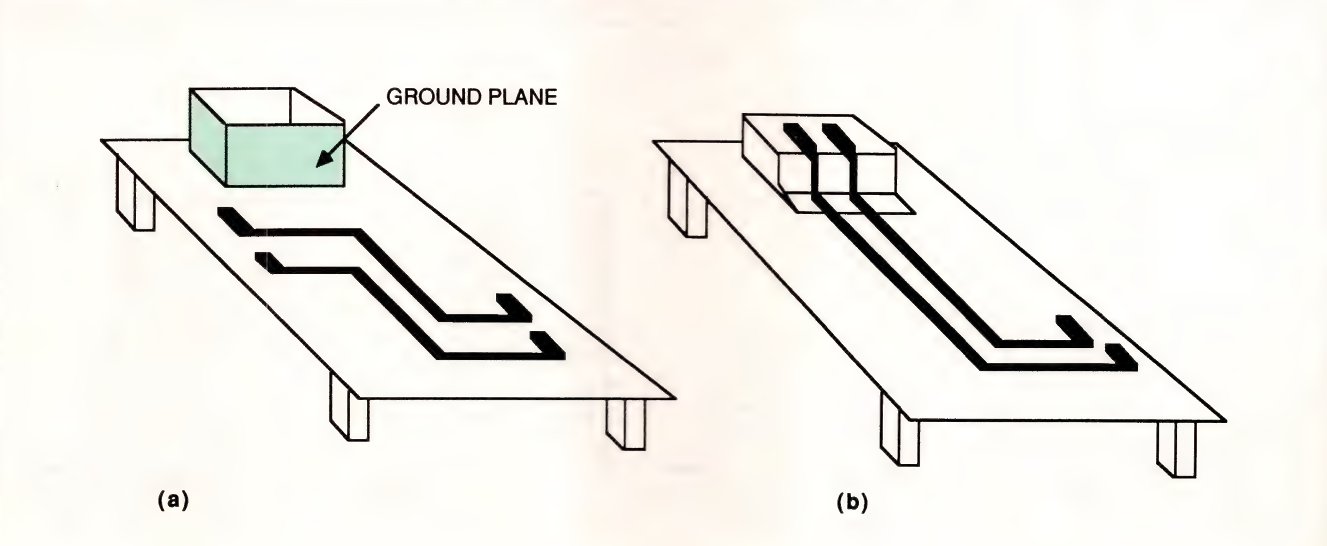

***Fig 2—Requirements for molded circuit boards vary** depending on the application. True 3-D boards **(b)** provide the same layout capabilities that flat boards do, but also let you run traces in three dimensions. However, you can't have areas completely enclosed by ground planes **(a)**, because the phototool techniques used for molded boards will not accommodate them.*

Selecting the right molding compound is an important factor in 3-D board design.

cannot expose the sections of the circuit shaded by the overhang, such a trace cannot be manufactured. In **b,** a trace runs through a tunnel. Such a conductor is also impossible to produce—there's no way to project light inside the tunnel. Instead of going through the plastic, consider going over it as shown in **c**. Although it's possible to produce a trace that goes over such a projection, you must design it very carefully. Because an angle of 1 to 3° is inherent in the molding process, the projection is actually tapered, being slightly wider at the bottom than at the top. However, to be compatible with the imaging process, the bottom inside corner must include a small fillet. The trace in **d** is the easiest to produce because the light source shines directly on all segments of the circuit trace.

A final note about locating traces on a 3-D board: If you're plating copper onto a 3-D board, be sure that the nearest pc trace is at least 12 mils from the nearest nonplated 3-D feature. Finally, as with 2-D pc-board design, it's always desirable to maximize conductor line widths and the spaces between conductors in order to facilitate production.

Mechanical possibilities increase flexibility

During the mechanical-design phase of a project, designers have the greatest opportunity to take advantage of the capabilities of molded boards. Features that require extra mechanical parts on a 2-D board can simply be molded as part of a 3-D assembly to speed production, reduce costs, and increase a product's capability. Also, a molded circuit board can reduce the number of parts you have to purchase, inventory, and assemble.

Although molding complexity varies from design to design, basic molded-circuit-board designs fall into three categories: molded flat pc boards, boards with added 3-D features, and true 3-D boards or assemblies. The difference lies in how you position your circuit conductors on the board and how you take advantage of the board's extra dimension.

Molded flat pc boards are much like their regular 2-D pc-board counterparts. The most significant difference deals with size; a 10×10-in. board with a 0.062-in. thickness is the largest size that can be molded. The size of the mold tool and mold press restricts the board's dimensions. Compound rheology (the ability of the molding material to flow) also limits a board's size.

Flat molded boards can incorporate special features that ease manufacturing. For example, a molded board could furnish special artwork-registration holes or breakaway tabs for handling. During manufacturing, the breakaway tabs provide convenient holding points. But after final testing, you can break the tabs off. Thus, you can manipulate the board during assembly without giving up precious board real estate (**Fig 4**) for holding points.

Like molded flat pc boards, 3-D-feature boards let you put the printed circuitry on the flat part of the

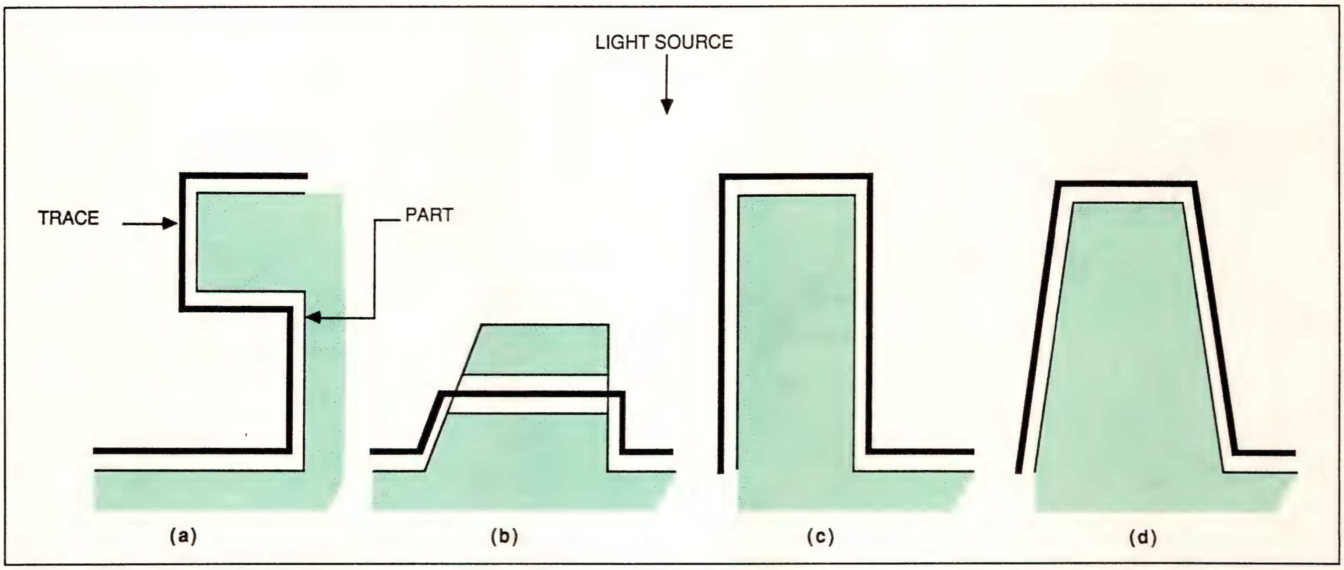

Fig 3—Exposure to the light source *is the most critical consideration in laying out traces on a molded circuit board. Overhangs **(a)** and tunnels **(b)** are taboo. Although it's possible to produce traces that run over highly vertical 3-D features **(c)**, sloping the walls of a projection **(d)** simplifies the circuit-production process.*

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Molded boards let you add registration and handling features without using any board space.

board. However, the 3-D feature boards let you incorporate 3-D features such as posts, standoffs, and some types of connectors in the same unit. You can also add recessed areas or rails that accommodate surface-mount devices. Such features let you increase the component density on the board. Likewise, you can reduce your product's cost by molding in standoffs, various types of mounting clips, RFI shields, connectors, and other devices. So instead of purchasing, storing, and assembling many parts, you incorporate them in one molded unit.

True 3-D boards offer the same design opportunities as those of 3-D-feature boards, but the circuit traces on true 3-D boards extend into all three dimensions (**Fig 2**). Because the circuit traces run in three dimensions, you must consider how you'll assemble the board or assembly. This factor may not be a major concern if workers assemble the boards by hand. However, if you're considering automated manufacturing, you must be sure that your equipment can place components on a 3-D board. In addition, you must consider any additional postprocessing operations—such as gold plating and solder masking—that the molded circuit board requires.

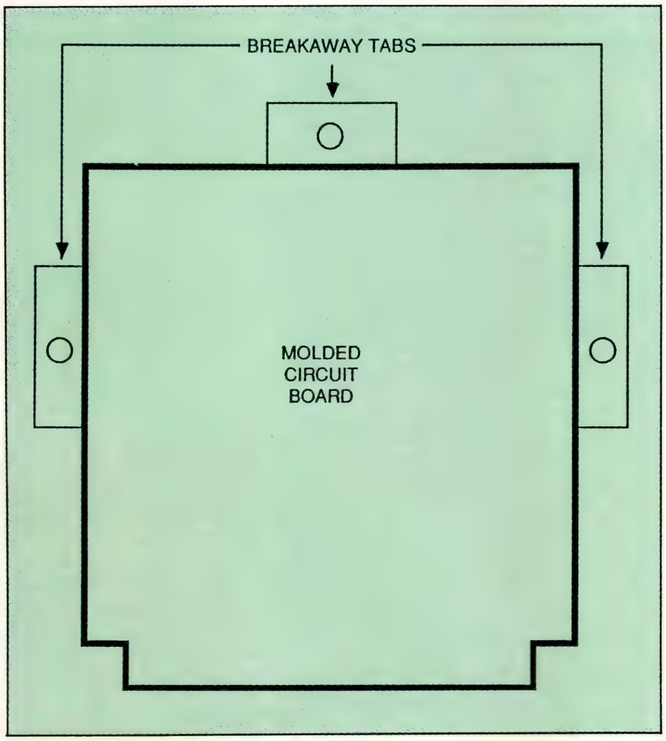

Fig 4—By building breakaway tabs into the molded board, *you can add registration and handling features to your design without sacrificing precious board real estate.*

Most of the limitations on the design of 3-D features result from considerations of moldability and part-design tradeoffs. Because board moldability is a major consideration, it's worth examining some commercially available compounds that briefly illustrate more of the choices you face.

Victrex PES (polyethersulfone) is the base resin for several compounds used to manufacture molded boards. This resin is a high-temperature, engineering-grade thermoplastic with favorable electrical, mechanical, and chemical characteristics that suit molded boards. Some of the compounds that incorporate Victrex PES include 3600G, an unfilled resin; PDX 86471, an experimental 10%-milled glass compound; 3601 GL20, a 20%-chopped glass compound; and PDX 87152, an experimental 30%-milled glass formulation. Other compounds can be formulated by combining various fillers and reinforcers.

The unfilled resin is easy to mold, but it's too flexible for many applications and is rarely used for molded boards. The 3601 GL20 compound is rigid, and its dielectric properties are well suited for molded boards. The chopped-glass fibers provide excellent reinforcement for the board. However, board shrinkage is anisotropic with this compound. The milled-glass compounds offer a reasonable compromise—they are more isotropic than 3601 GL20 and offer more rigidity than 3600G.

EDN

Author's biography

John D Williams is a senior design engineer at the Electronics Div of ICI Americas Inc (Newark, DE), where he manages the division's design group. He has been with the company for one year. John is a member of the IEEE and the ACM, and he has a BA degree from Milligan College.

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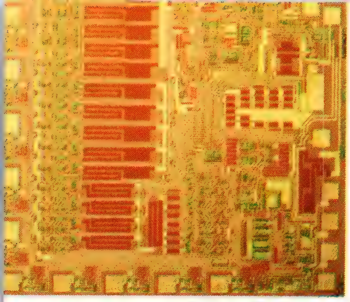

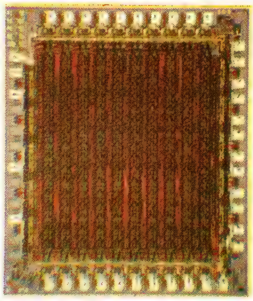

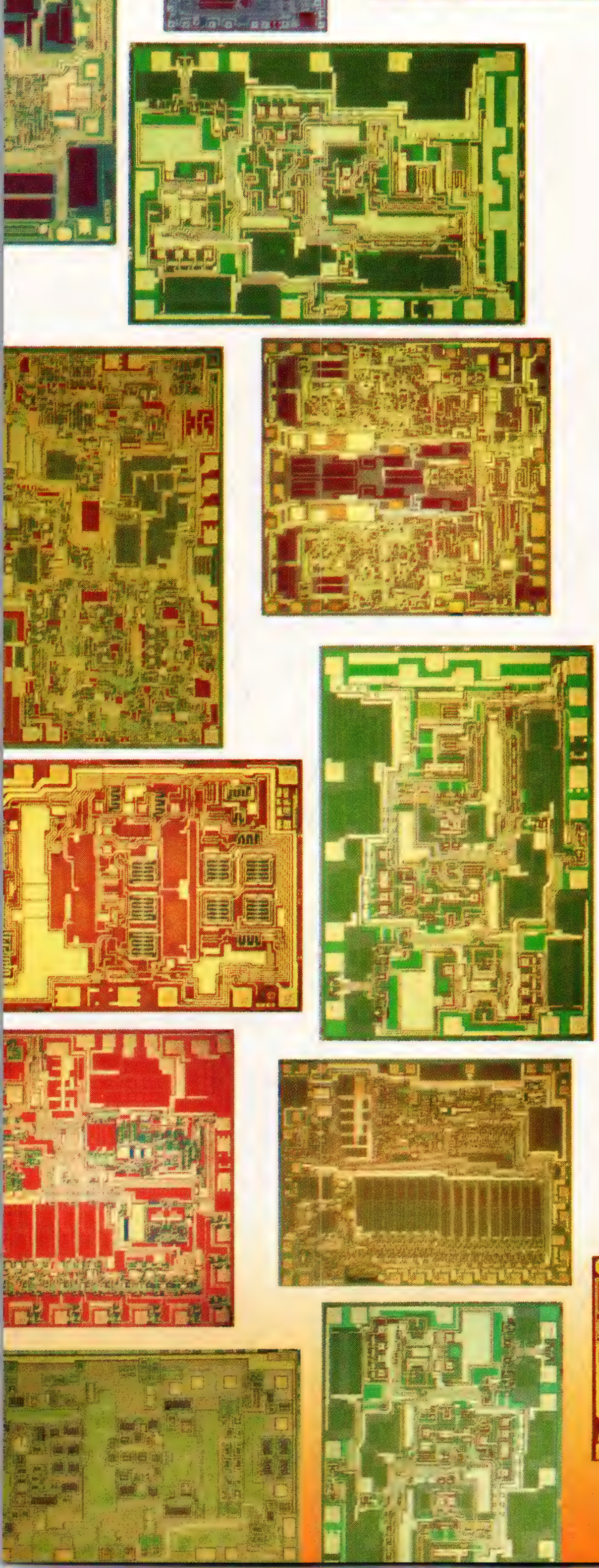

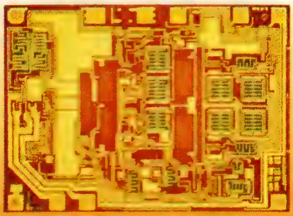

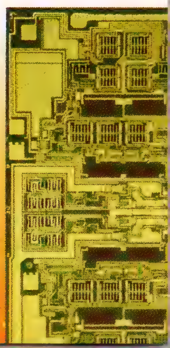

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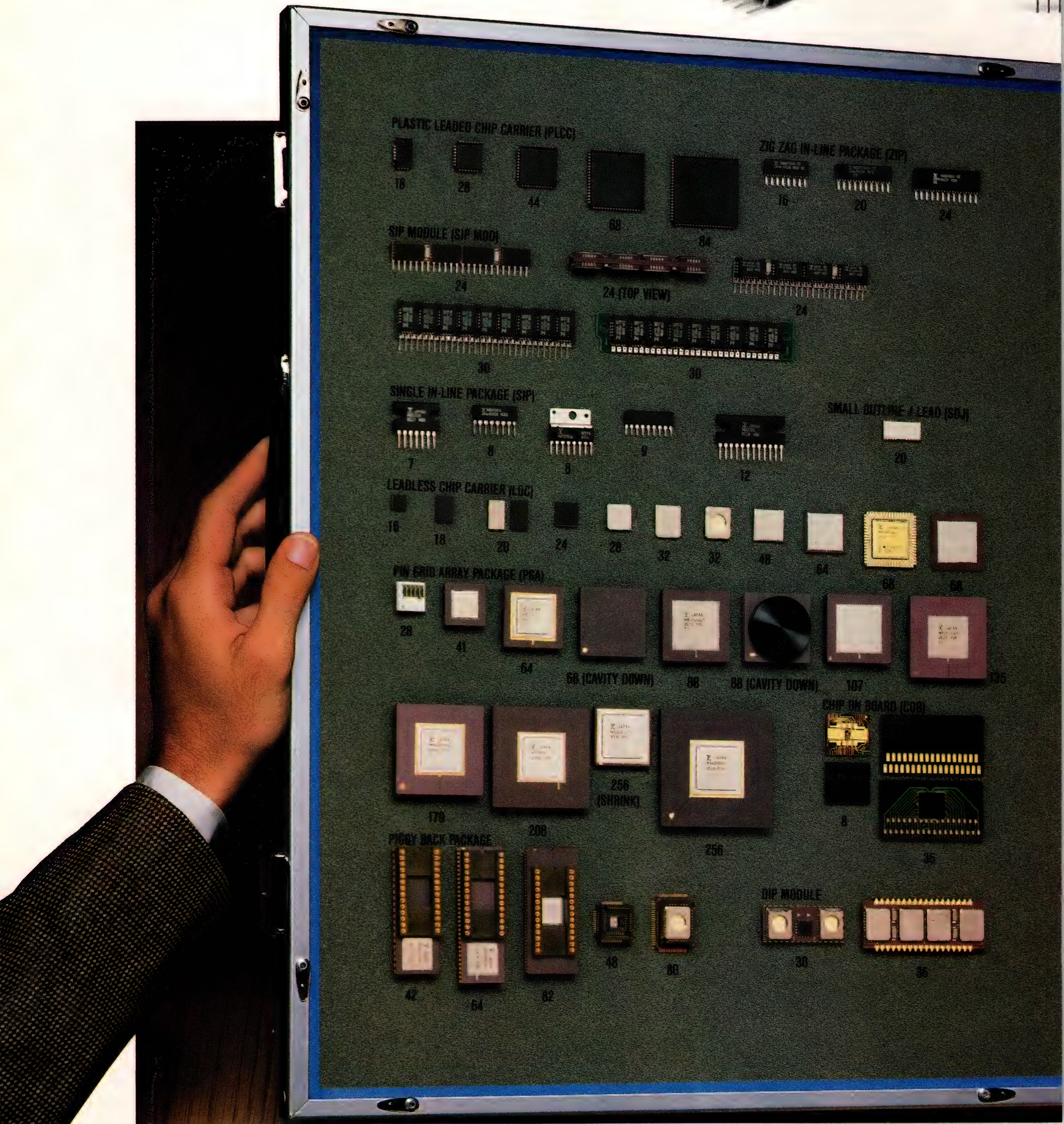

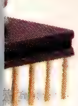

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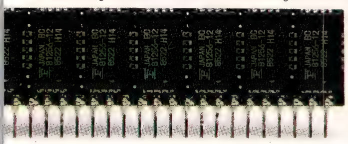

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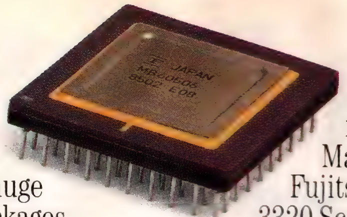

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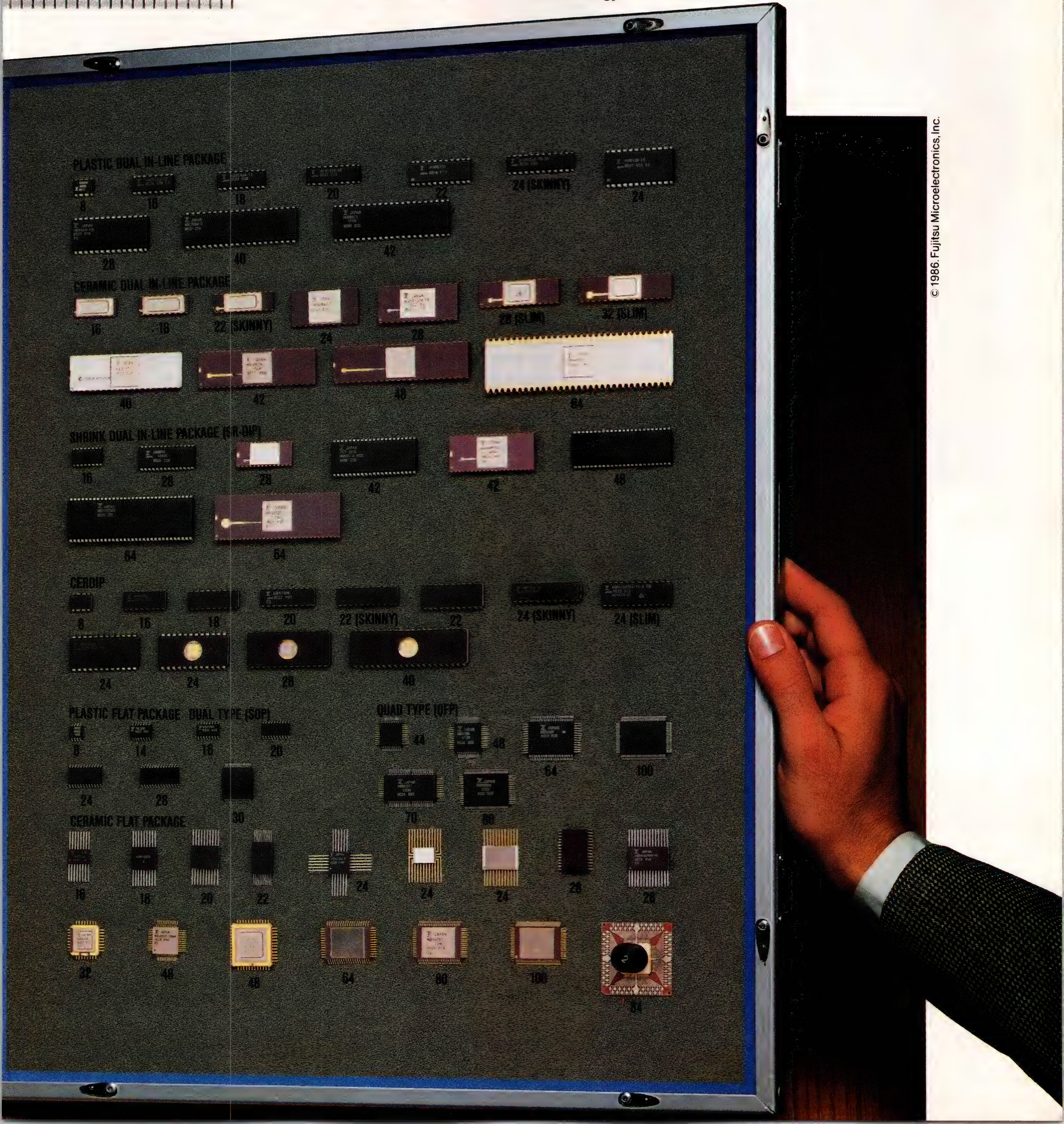

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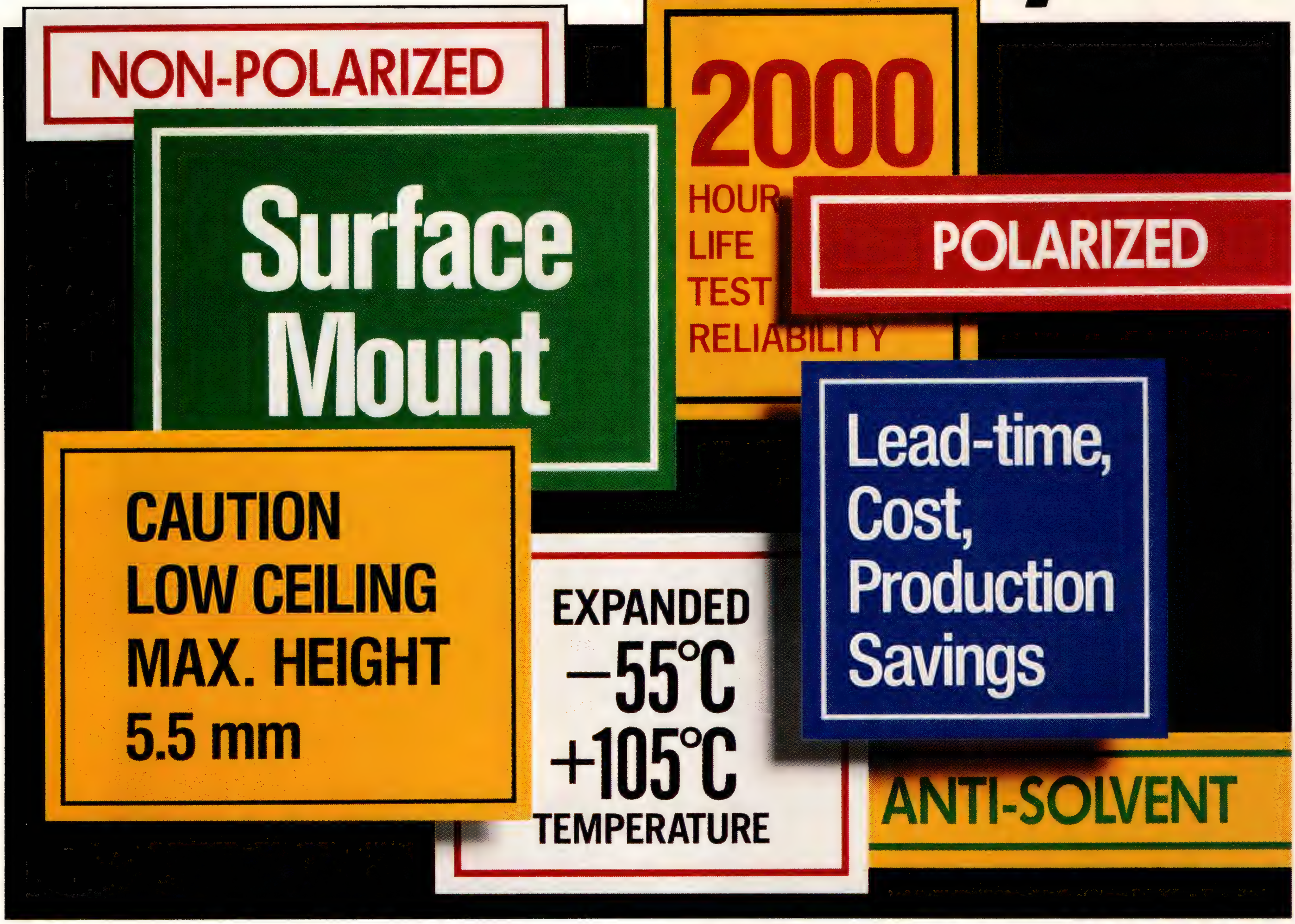

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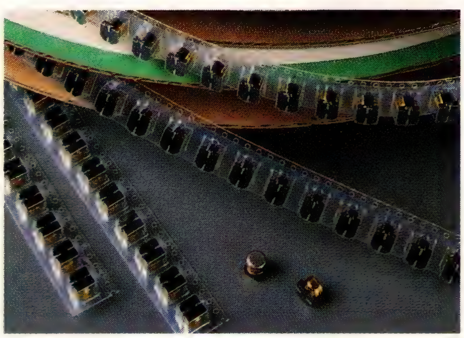

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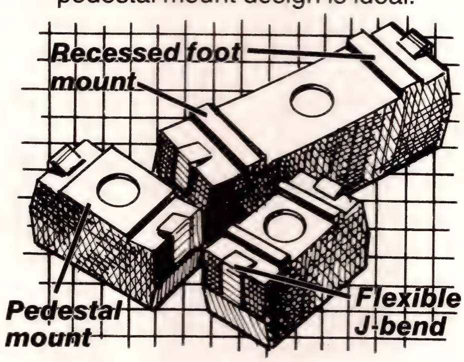

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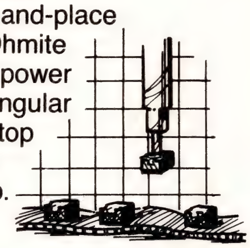

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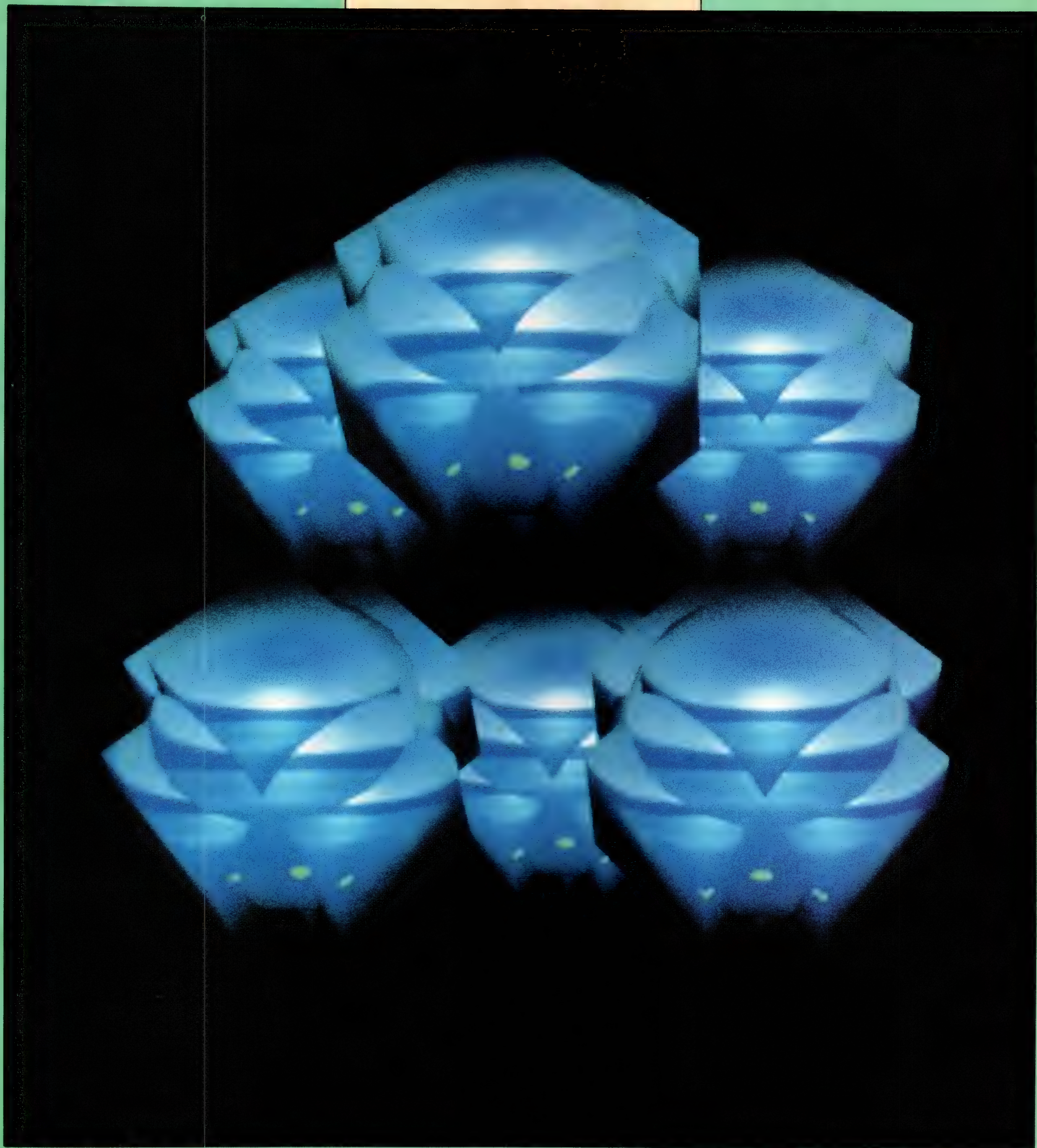

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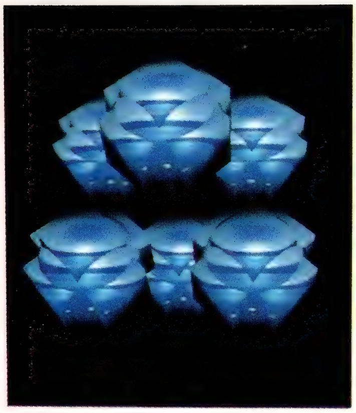

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UNIX: looking better. *Young, Jeremy, Managing Editor; Manuel, Tom, Managing Editor; Electronics, 10/15/87, pg 67, 3 pgs.*

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Automatic component-placement programs speed pc-board layout and reduce costs. *Freeman, Eva, Associate Editor; EDN, 06/11/87, pg 57, 5.33 pgs.*

CASE capabilities grow. *Meng, Brita, Technical Editor; ESD, 06/87, pg 99, 2 pgs.*

CASE data exchange unifies product design stages. *Gabay, Jon, Contributing Editor; Computer Design, 06/15/87, pg 40, 2 pgs.*

CASE tools run on an expanded range of computer systems. *Terry, Chris, Associate Editor; EDN, 07/23/87, pg 220, 7.5 pgs.*

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Interchange standard for CASE gathers support. *Goering, Richard, Senior Editor; Computer Design, 09/01/87, pg 28, 1.5 pgs.*

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Low-cost CAE software comes of age. *Milne, Bob, Senior Editor; Electronic Design, 08/20/87, pg 33, 4 pgs.*

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In-circuit emulators keep pace with 16- and 32-bit µPs. *Everett, Chris, Regional Editor; EDN, 07/23/87, pg 252, 8 pgs.*

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How to hike productivity in military software. *Waller, Larry, News Bureau—Los Angeles; Electronics, 09/03/87, pg 97, 2 pgs.*

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Laser diodes improve portable bar-code scanning. *Harbert, Tammi, Senior Editor/News; EDN News, 10/87, pg 8, 1.5 pgs.*

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Cache accelerates operation of 32-bit μP systems. *Nalesnik, Robert, Fairchild Europe Semiconductor; EDN, 05/28/87, pg 183, 5 pgs.*

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Designers build smarts into their CAE tools with expert-system shells. *Schindler, Max, Software Editor; Electronic Design, 07/09/87, pg 71, 6 pgs.*

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Electronic documentation tools blend text and graphics for CAE. *Mosley, J D, Regional Editor; EDN, 09/03/87, pg 81, 5.33 pgs.*

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Program brings analog CAE to personal computer level. *Seiter, Charles, Borland International; Electronic Design, 09/03/87, pg 99, 3.5 pgs.*

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Walk through board design with an all-in-one system. *Poniatowski, Martin, Hewlett-Packard; Electronic Design, 09/87, pg 79, 3 pgs.*

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Workstations. *Shear, David, Regional Editor; EDN, 10/29/87, pg 169, 8 pgs.*

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Distributed operating system facilitates CIM. *Barr, John, Computer X; Computer Design, 08/01/87, pg 75, 6 pgs.*

Gap between CAE and ATE is narrowing. *McLeod, Jonah, Managing Editor; Electronics, 10/01/87, pg 72, 3 pgs.*

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Buscon/87: Technical sessions and products for computer-bus designers and users. *Staff; EDN, 09/17/87, pg 97, 2 pgs.*

NCC revival plan won't help this year. *Iversen, Wesley R, Department Editor; Electronics, 06/11/87, pg 42, 1 pg.*

Ray tracing leads the way at Siggraph. *Young, Jeremy, Managing Editor; Electronics, 07/23/87, pg 53, 1 pg.*

Salon des Composants sessions will emphasize developments in passive components. *Harold, Peter, European Editor; EDN, 10/29/87, pg 109, 1 pg.*

Software stars at the Design Automation conference. *McLeod, Jonah, Managing Editor; Electronics, 06/25/87, pg 57, 3 pgs.*

The second bipolar meeting looks like a hot one. *Cole, Bernard C, Managing Editor; Electronics, 09/03/87, pg 45, 1.5 pgs.*

Wescon/87 will highlight electronics in the entertainment and broadcasting sectors. *Small, Charles H, Associate Editor; EDN, 10/29/87, pg 97, 2.67 pgs.*

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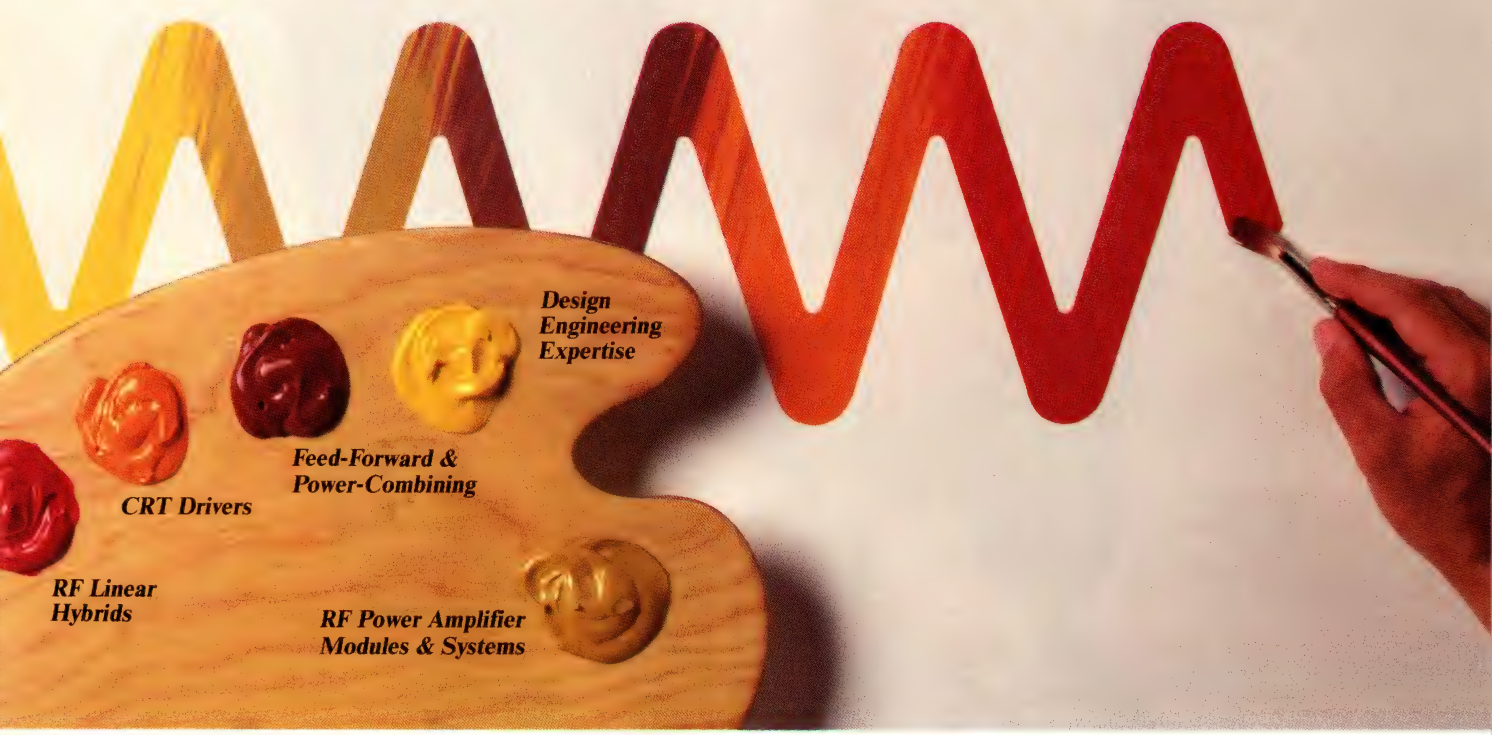

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Connectors

Motherboards' plane in the back cured, thanks to improved connector design, multilayer boards, surface mounting. *Biancomano, Vincent, Components&Packaging Editor; Electronic Design, 08/20/87, pg 69, 5.5 pgs.*

Surface-mount connectors. *Mosley, J D, Regional Editor; EDN, 10/01/87, pg 142, 7.5 pgs.*

Update on fiber-optic connectors. *Chin, Spencer, Associate Editor; Electronic Products, 09/15/87, pg 23, 1.5 pgs.*

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It's design-in time for ISDN: OEMs find the going rough. *Shandle, Jack, New Products; Electronics, 10/01/87, pg 63, 3 pgs.*

It's time for MCC to fish or cut bait. *Lineback, J R, News Bureau—Dallas; Electronics, 06/25/87, pg 32, 1 pg.*

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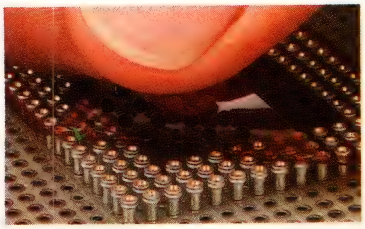

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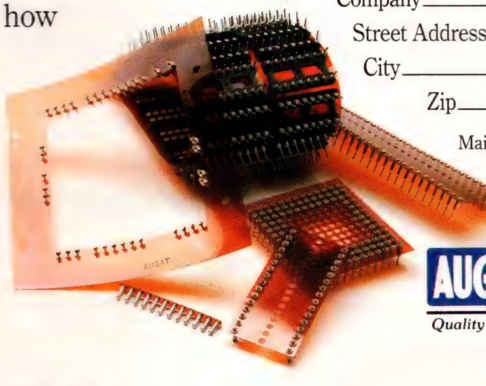

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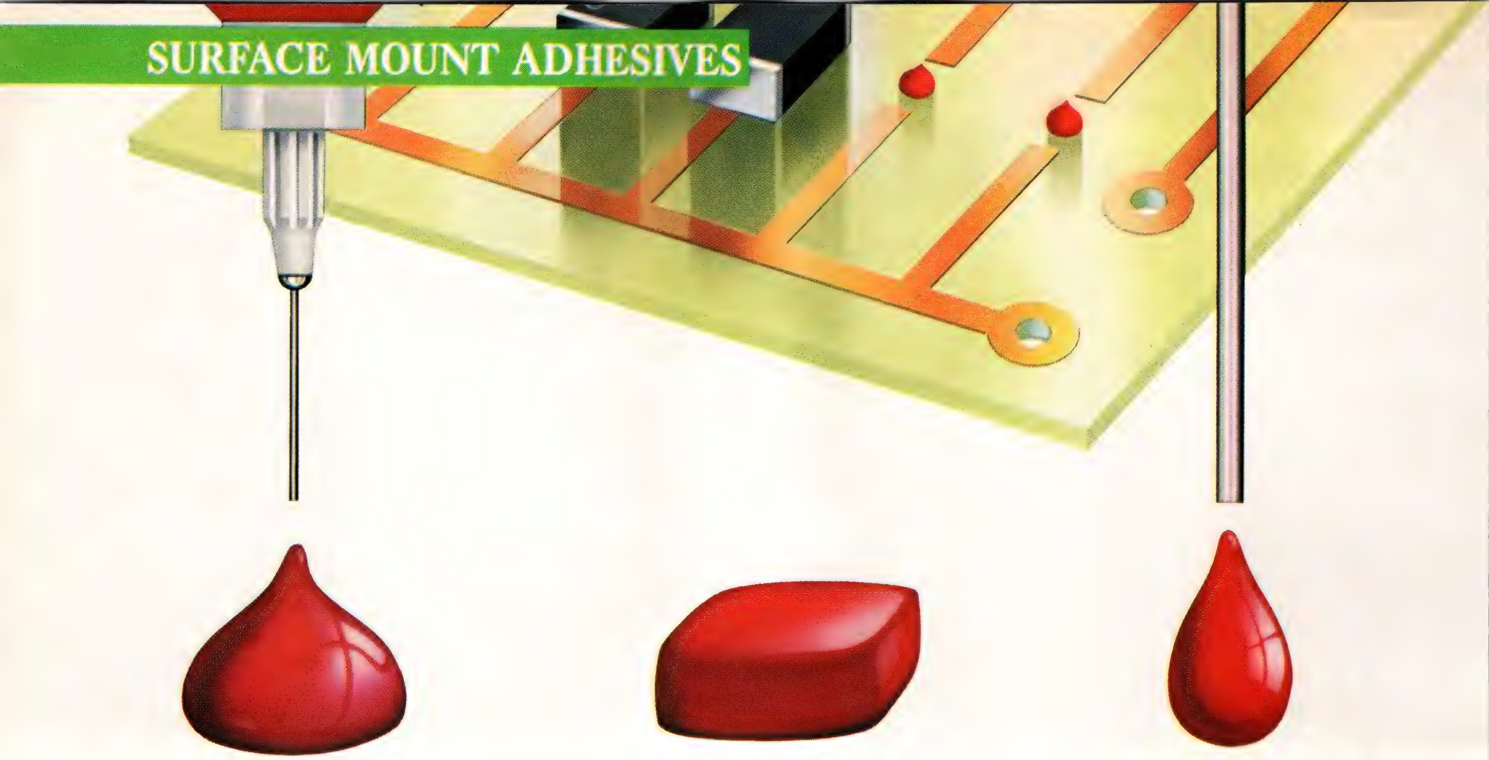

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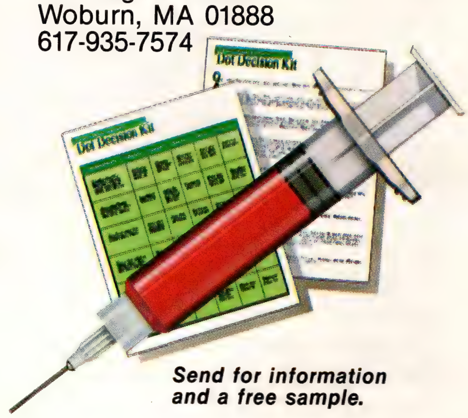

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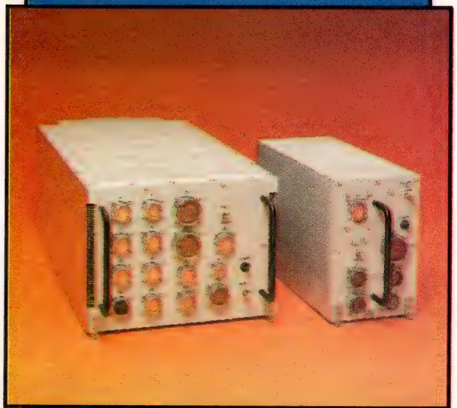

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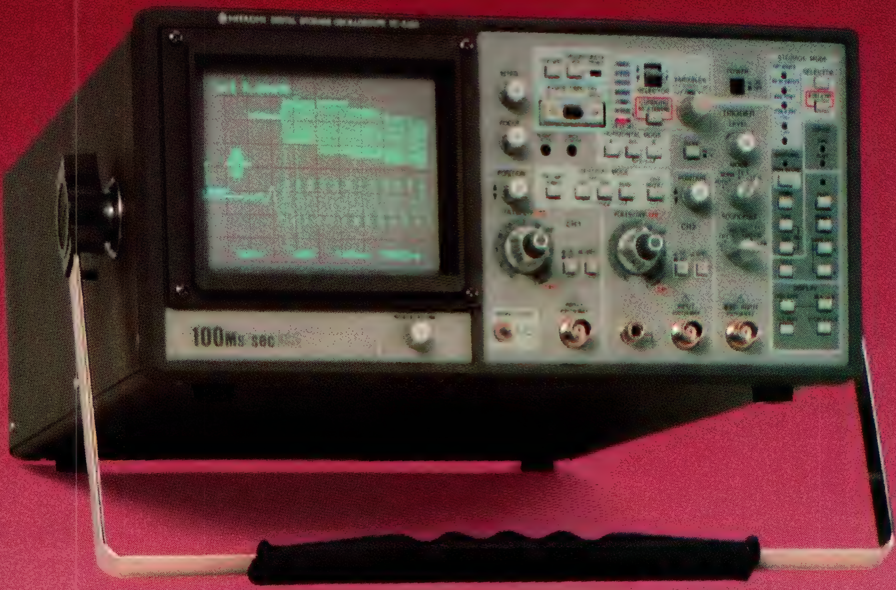

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CD ROM drive makers swarm to half-heights. *Chester, Michael, Southwestern Editor; Electronic Products, 07/01/87, pg 16, 1.5 pgs.*

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GaAs ICs form core of oscilloscope. *Roberts, Michael, et al, Gigabit Logic; EDN News, 06/18/87, pg 8, 0.5 pgs.*

Handheld instrument gives benchtop performance. *Pine, Ken, Dolch American Instruments; EDN News, 10/87, pg 10, 1 pg.*

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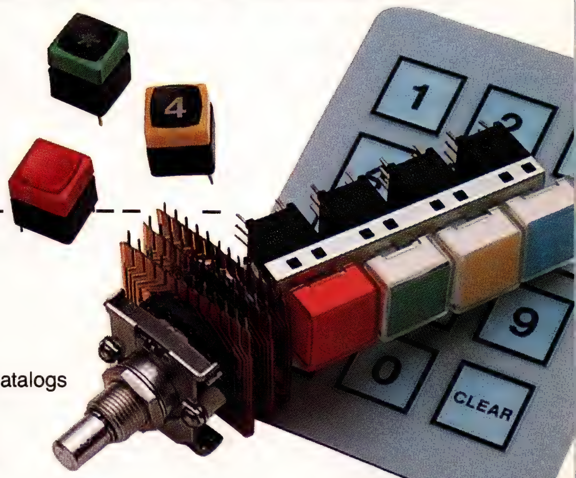

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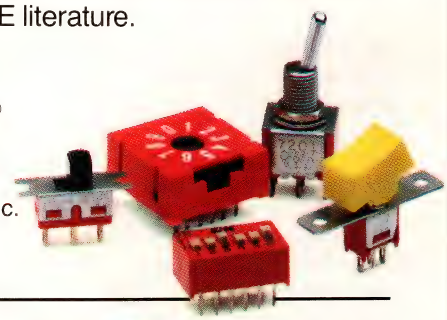

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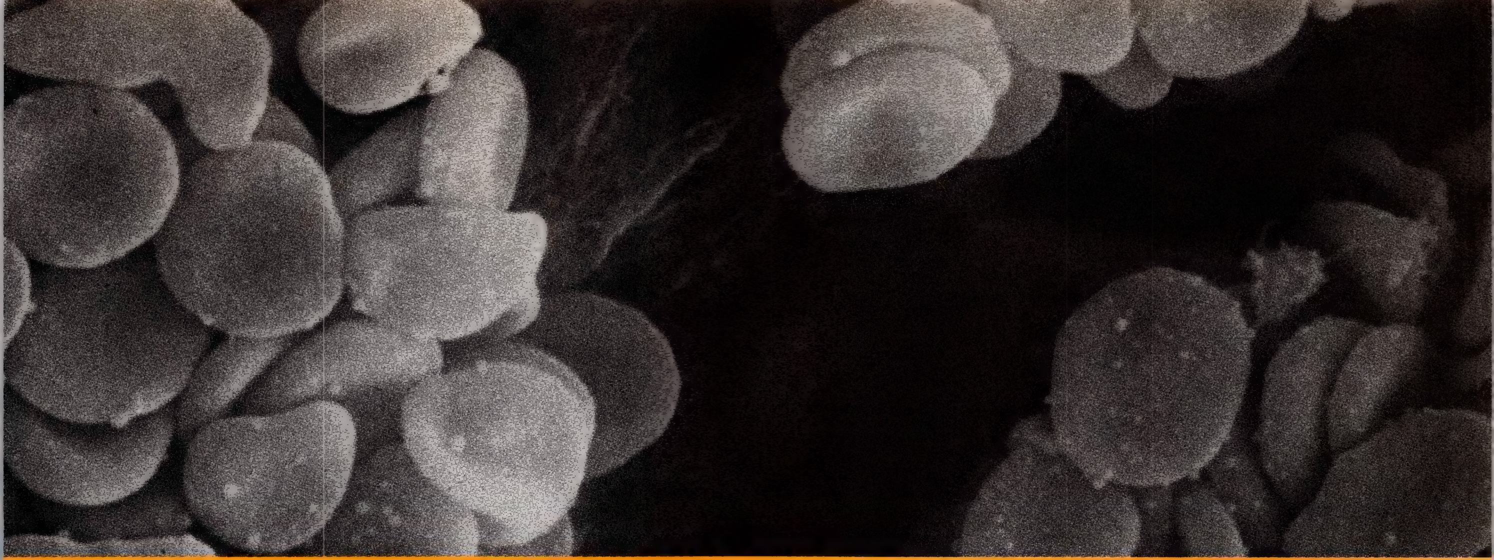

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DESIGN NOTES

Number 6 in a series from Linear Technology Corporation — January, 1988

Operational Amplifier Selection Guide for Optimum Noise Performance

George Erdi

The LT1028 is the lowest noise op amp available today. Its voltage noise is less than that of a 50Ω resistor. In other words, if the LT1028 is operated with source resistors in excess of 50Ω, resistor noise will dominate. If the application requires large source resistors, the LT1028's relatively high current noise will limit performance, and other op amps will provide lower overall noise.

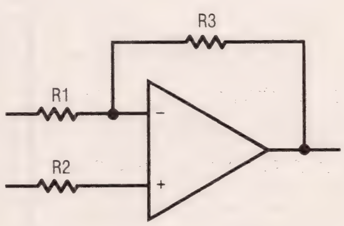
In general, the total noise of any op amp (referred to the input) is given by:

$$\text{total noise} = \sqrt{(\text{voltage noise})^2 + (\text{resistor noise})^2 + (\text{current noise} \times R_{eq})^2}$$

where,

resistor noise $= 0.13\sqrt{R_{eq}}$ in $nV/\sqrt{Hz}$

and R_{eq} = equivalent source resistance $= R2 + R1//R3$



Several conclusions can be reached by inspection of the equation:

(a) To minimize noise, resistor values should be minimized to make the contribution of the second and third terms of the equation negligible. Don't forget, however, that feedback resistor R3 is a load on the output.

(b) Total noise is dominated by:
(i) voltage noise at low R_{eq},
(ii) resistor noise at mid R_{eq},
(iii) current noise at high R_{eq}, because resistor noise is proportional to $\sqrt{R_{eq}}$, while the current noise contribution to total noise is proportional to R_{eq}.

The table below lists which op amp gives minimum total noise for a specified equivalent source resistance. A two step prcoedure should be followed to optimize noise:

(1) Reduce equivalent source resistance to a minimum allowed by the specific application.

(2) Enter the table to find the optimum op amp.

The table actually has two sets of devices: one for low frequency (instrumentation), one for wideband applications. The slight differences between the two columns occur because voltage and current noise increase at low frequencies (below the so-called 1/f corner) while resistor noise is flat with frequency.

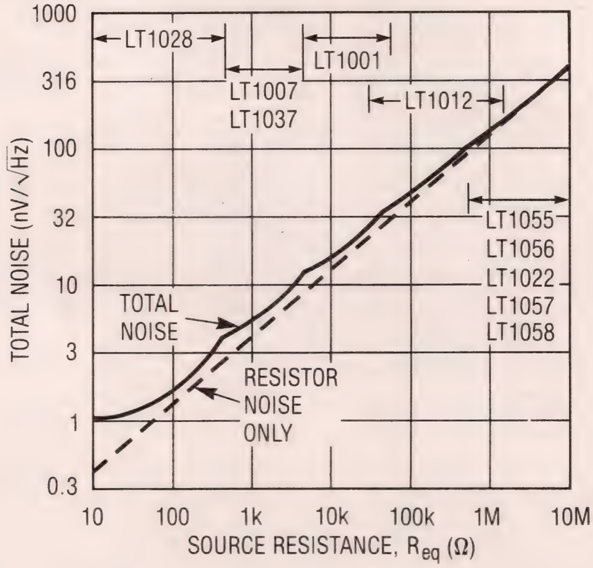
Best Op Amp for Lowest Noise vs Source Resistance

SOURCE R (R_{eq})	BEST OP AMP	
	@ LOW FREQ. (10Hz)	@ WIDEBAND (1kHz)
0Ω to 400Ω	LT1028	LT1028
400Ω to 1k	LT1007/37	LT1028
1k to 4k	LT1007/37	LT1028, LT1007/37
4k to 15k	LT1001	LT1007/37
15k to 30k	LT1001	LT1001, LT1007/37
30k to 70k	LT1001, LT1012	LT1001
70k to 150k	LT1012	LT1001, LT1012 LT1055/56/22, LT1057/58
150k to 600k	LT1012, LT1006/13/14	LT1012, LT1006/13/14 LT1055/56/22, LT1057/58
600k to 2M	LT1012 LT1055/56/22, LT1057/58	LT1012, LT1006/13/14 LT1055/56/22, LT1057/58
2M to 10M	LT1055/56/22, LT1057/58	LT1012 LT1055/56/22, LT1057/58
>10M	LT1055/56/22, LT1057/58	LT1055/56/22, LT1057/58

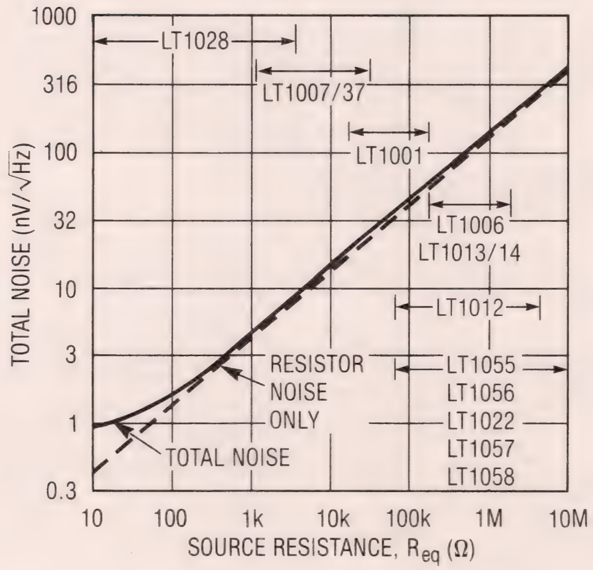
The actual achievable total noise is plotted at 10Hz and 1kHz. The striking feature of these plots is that with the proper selection of op amps total noise is dominated by equivalent source resistor noise over a five decade (100Ω to 10MΩ) range.

For Op Amp literature call **800-637-5545.** For help with an application call (408) 432-1900, Ext. 361.

10Hz Total Noise vs Equivalent Source Resistance



1kHz Total Noise vs Equivalent Source Resistance



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IM/GP 1287 160K

EDITED BY TARLTON FLEMING

Three-chip transceiver handles 64k bps

Jens G Paetau
Exar Corp, San Jose, CA

The telecomm transceiver of **Fig 1** provides data reception, data transmission, and clock recovery for data rates of 64k bps or less. The phase-shift comparator (IC_3) enables the PCM line receiver (IC_1), which is capable of T1 reception at rates as high as 2M bps, to extract and regenerate data at the lower data rates. This receiver differs from that of a T1 application only in the circuit's pole and zero locations, which are dictated by the line's characteristic impedance.

The isolated, formatted, bipolar input signal drives the input side of transformer T_1. On the output side of T_1, the T pad of the 180Ω resistors provides impedance matching to the 135Ω line and 6-dB signal attenuation. In addition, the T pad serves as a set of dropping resistors in front of clamp diodes D_1 through D_4, which protect the preamplifier from high-voltage transients.

The circuit can reconstruct a data signal that has accumulated as much as 36 dB of attenuation and line distortion. (This decibel level corresponds to a transmission distance of five miles max over #22-AWG cable at 70°F.) In response to such a signal, IC_1's internal preamplifier produces the 1.4V p-p output necessary to properly trigger the internal clock and data circuits. To set the necessary dynamic range, choose the ratio R_5/R_6.

The amplified signal, after triggering the internal clock and data circuits, excites the external tank circuit L_1/C_{10}, which oscillates at the desired transmission frequency. The tank's Q determines the number of sequential zeros allowed on the line. (A higher Q allows the tank to oscillate longer, thereby supporting a longer sequence by maintaining the necessary clock signal.) To allow an equivalent-length sequence of ones, you can employ a zero-suppression coding scheme such as B8ZS.

Op amp IC_3 adds to IC_1's clock output a 90° phase shift, which is necessary to strobe IC_1's data latches properly and to recover the data with full bandwidth. The dual line driver (IC_2) serves as a data transmitter; R_{17} and R_{18} determine the transmitter's output impedance and the output signal's amplitude. **EDN**

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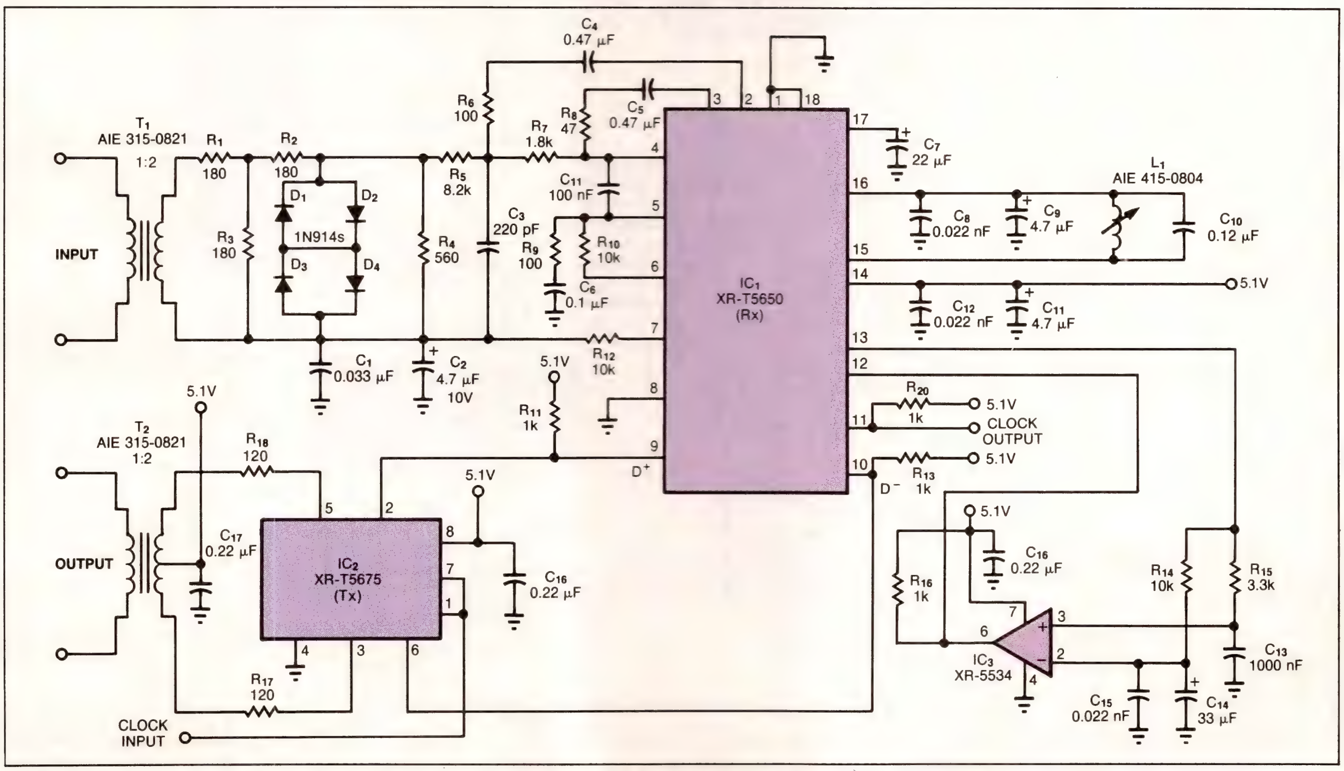

Fig 1—This data transceiver, suitable for data rates of 64k bps or less, is built with chips capable of much higher data rates.

Digital one-shot has power-on preset

Robert McCarthy
Sun Electric Corp, Crystal Lake, IL

The **Fig 1** circuit is a digital monostable multivibrator (one-shot) that, at power-up, produces an output pulse whose width is a preset default value. During power-up, the address-decode and power-on-reset signals disable the output of latch IC_4. Thus, at that time, the 10-kΩ pull-up and pull-down resistors preset comparator IC_3 to the desired pulse-width default value.

When the system asserts the proper address and data signals, the circuit enables IC_4's output. The time intervals produced have an accuracy (plus or minus one clock cycle) that increases with the programmed output duration. Using a 5-kHz clock, for example, you can produce a 5-msec interval (25 clock cycles) with ±2% accuracy; a 10-msec interval with ±1% accuracy; or a 51.2-msec interval with ±0.2% accuracy. **EDN**

To Vote For This Design, Circle No 747

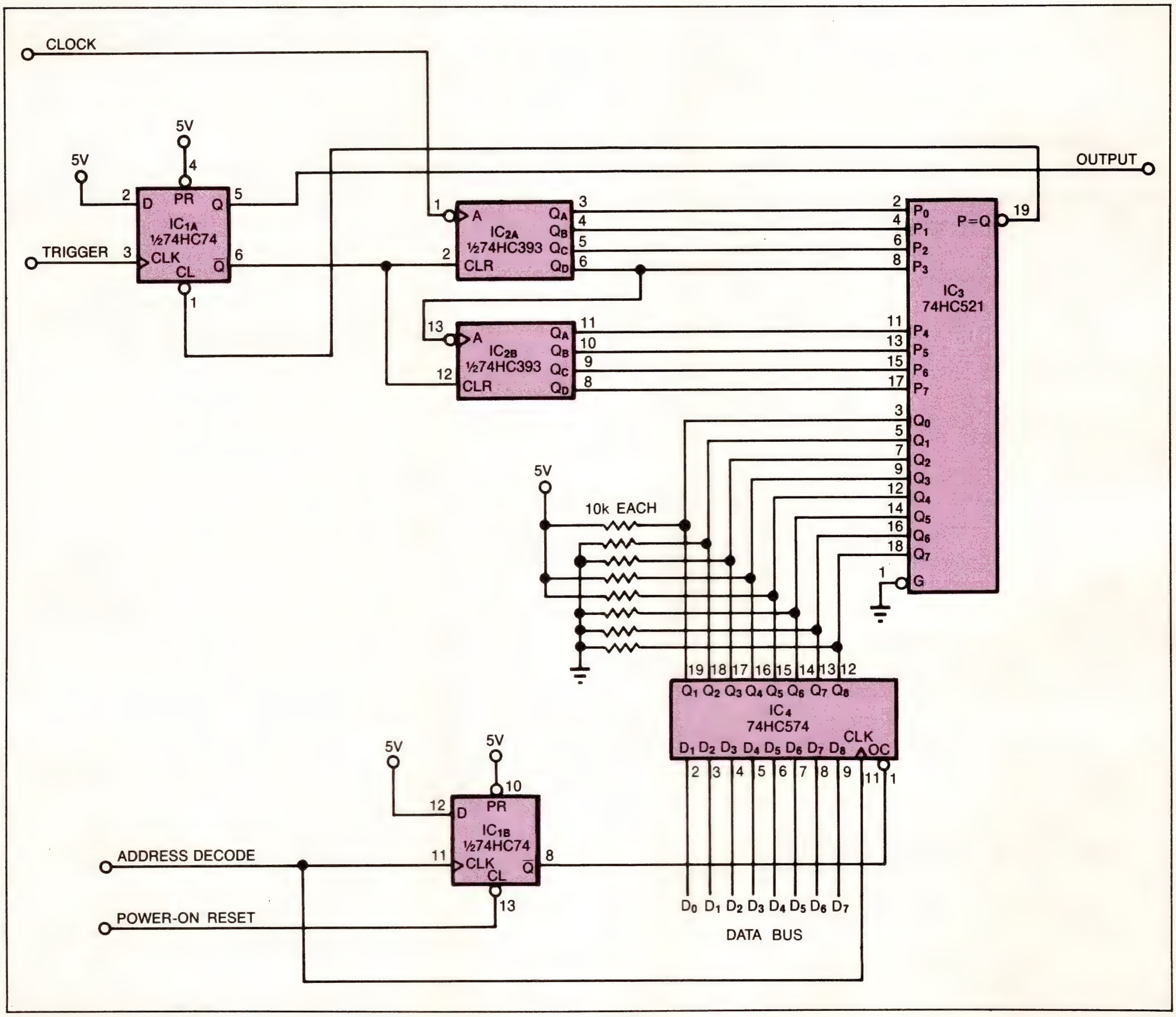

Fig 1—At power-up, this digital one-shot produces a pulse whose width is a default value determined by the 10-kΩ pull-up and pull-down resistors. Subsequently, you program the output pulse widths with 8-bit resolution.

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LOW PASS **Model**	*LP-	10.7	21.4	30	50	70	100	150	200	300	450	550	600	750	850	1000
Min. Pass Band (MHz) DC to		10.7	22	32	48	60	98	140	190	270	400	520	580	700	780	900
Max, 20dB Stop Frequency (MHz)		19	32	47	70	90	147	210	290	410	580	750	840	1000	1100	1340

Prices (ea.): P $9.95 (6-49), B $24.95 (1-49), N $27.95 (1-49), S $26.95 (1-49)

HIGH PASS **Model**	*HP-	50	100	150	200	250	300	400	500	600	700	800	900	1000
Pass Band (MHz)	start, max.	41	90	133	185	225	290	395	500	600	700	780	910	1000
	end, min.	200	400	600	800	1200	1200	1600	1600	1600	1800	2000	2100	2200
Min. 20dB Stop Frequency (MHz)		26	55	95	116	150	190	290	365	460	520	570	660	720

Prices (ea.): P $12.95 (6-49), B $27.95 (1-49), N $30.95 (1-49), S $29.95 (1-49)

*Prefix P for pins, B for BNC, N for Type N, S for SMA   *example:* **PLP-10.7**

CIRCLE NO 162

C105 REV.D

Low-current voltage tripler is inexpensive

Henry Yiu
Endevco, San Juan, CA

You can expand the low-cost ($2.25) voltage tripler of **Fig 1** by adding more stages, and you can lower the circuit's output impedance by adding more buffer inverters in parallel. To obtain a negative-voltage converter, simply reverse the diode and capacitor polarities and connect the V_{IN} terminal to ground. The circuit oscillates at approximately 350 kHz when R_{OSC}=1 kΩ and at approximately 4 kHz when R_{OSC}=100 kΩ. For the circuit as shown, **Fig 2** charts the efficiency and the load voltage vs load current. **EDN**

To Vote For This Design, Circle No 748

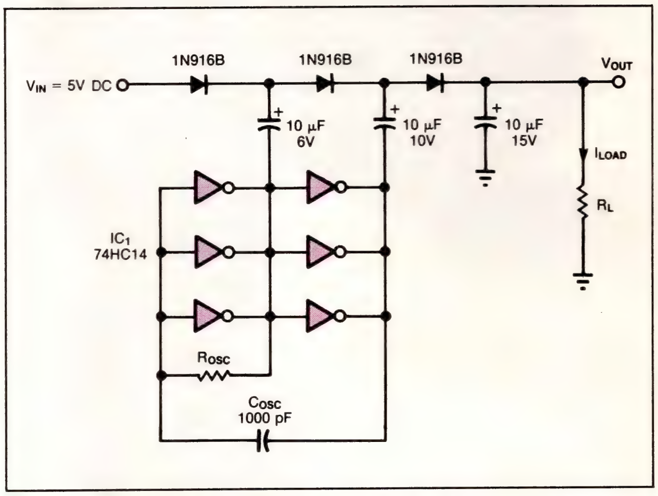

Fig 1—This circuit generates a 15V output by tripling V_{IN}.

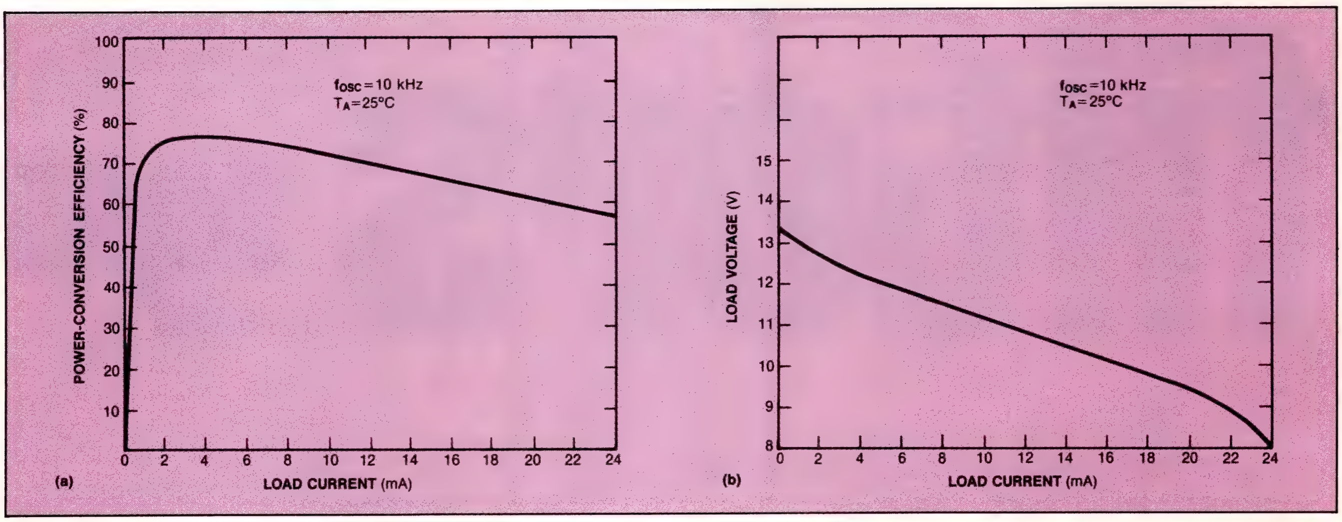

Fig 2—These curves show Fig 1's power-conversion efficiency (a) and load voltage (b) vs load current.

Precision load achieves 5-kV compliance

Dave Cuthbert
Hughes Aircraft Corp, Torrance, CA

Fig 1's circuit is a precision, 5- to 2000-µA constant-current load for 0- to 5-kV positive voltages. The load impedance is 250 GΩ shunted by 15 pF. If you connect a floating power supply to the output, the circuit becomes a current source with an output compliance as high as 5 kV.

The circuit's reference potential is the −30V supply. The R_1/R_2 divider lets you vary the voltage at IC_1's noninverting input over a 2V range (−30 to −28V) by

adjusting R_2. In turn, the op amp drives MOSFET Q_1, which controls current through the sense resistor (R_3). Q_1's drain-to-source voltage determines the vacuum tube's cathode current by controlling the tube's grid-to-cathode voltage.

Because the control grid connects to R_3, the grid-emission current adds to the sensed cathode current. The screen current doesn't add to the cathode current because a 9V battery powers the screen grid. The normal screen current is about 20 μA, so an alkaline battery will last about a year. You should float the filament supply and operate the 6.3V ac filaments at 5V ac to provide better control of plate currents below 10 μA.

To achieve the 250-GΩ output resistance (indicated by a 20-nA change in plate current for a 5-kV change in V^+), the tube's cathode must be well insulated from ground. Also, you should use a low-leakage transformer in the filament's floating-supply circuit and insulate the case of the screen-supply battery. **EDN**

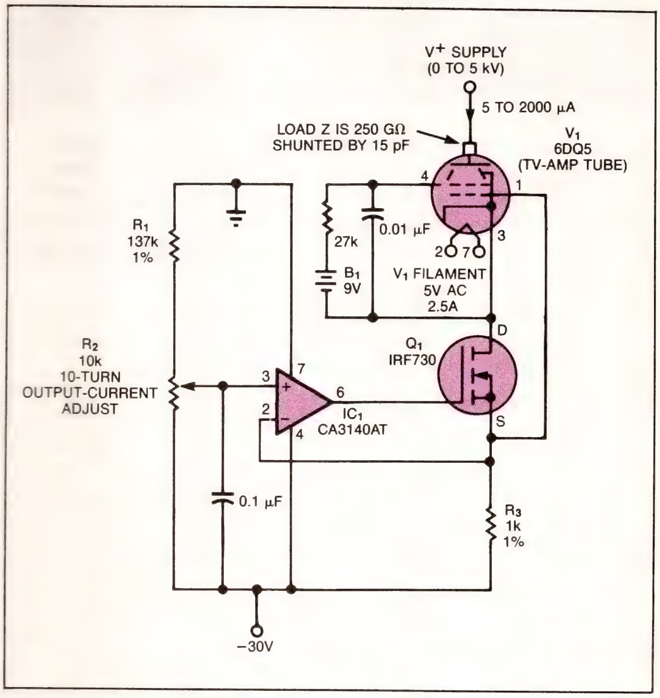

*Fig 1—**Using a vacuum tube to dissipate power,** this constant-current load (or current source) has a 5-kV compliance voltage.*

To Vote For This Design, Circle No 749

Op amp improves supply-voltage tracking

Jerry Fitzpatrick
Dytel Corp, Schaumburg, IL

In the regulated, bipolar power supply of **Fig 1**, an op amp causes the ±15V outputs to track one another regardless of load conditions. In many designs, feedback adjusts the output of a slave supply to mirror that of a stable master supply. The master can't compensate, however, for variations in the slave output caused by heavy, changing loads, and output tracking deteriorates as a result.

The op amp in **Fig 1** accomplishes bilateral tracking by monitoring both output-supply rails. You can apply this technique to various linear- and switching-regulator designs. When the outputs are equal, the op amp's output is zero and therefore has no effect on the circuit. This output becomes nonzero in response to load variations, opposing any tendency toward inequality between the two output voltages.

R_1 and R_2 set the output-voltage magnitudes; you can add a small voltage-adjustment potentiometer in series with one of these resistors. The output-voltage accuracy depends directly on the matching between the sense resistors (R_4 and R_5). Only the op amp's slew rate limits the circuit's response to load transients; if you desire a slower response, add a capacitor across the feedback resistor (R_3). Finally, note that you should provide electronic shut-down circuitry or a fuse to protect the circuit against output short circuits. **EDN**

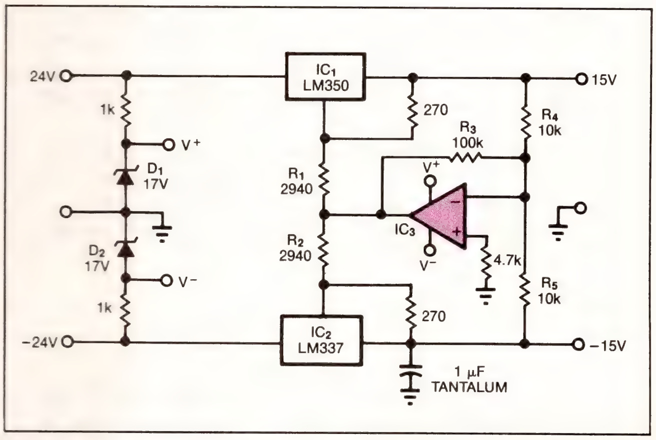

*Fig 1—**This regulated, bipolar supply** maintains equal-valued outputs that track despite output-load variations.*

To Vote For This Design, Circle No 750

DESIGN IDEAS

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ISSUE WINNER

The winning Design Idea for the October 15, 1987, issue is entitled "Digital ICs form programmable divider," submitted by Steve Lubs of the Dept of Defense (Washington, DC).

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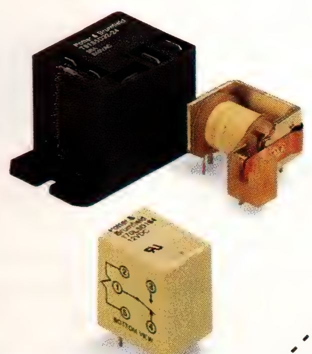

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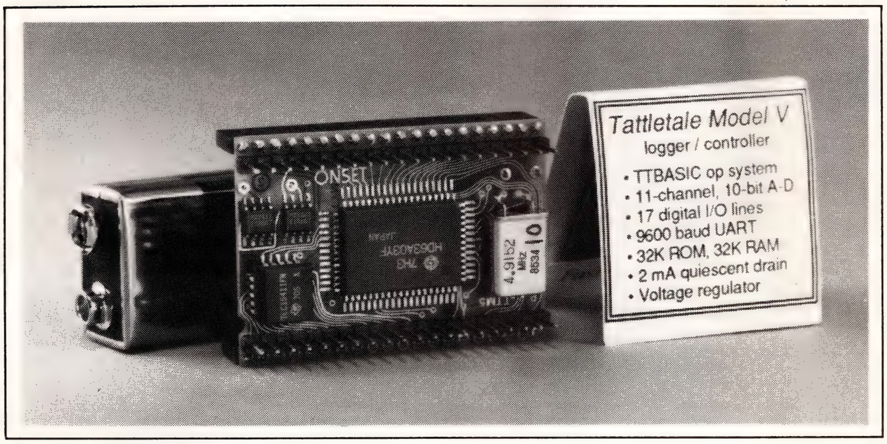
CIRCLE NO 161

COMPUTERS & PERIPHERALS



ACQUISITION MODULE

- *Matchbook-size module has 11 10-bit A/D channels*
- *Has 17 digital I/O lines, a UART, and 28k bytes of RAM*

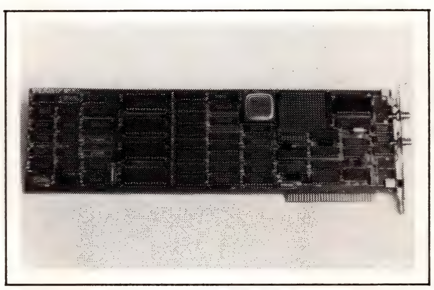
The Tattletale Model V is an acquisition module that contains a 10-bit A/D converter that can sample 11 analog input channels at 100 Hz. It also has 17 programmable digital I/O lines, a 9600-baud UART, low-power modes, and 28k bytes of RAM. The module measures 1.4×2×0.8 in. and operates between 0 and 70°C. It runs from a 6.5 to 15V battery supply with a typical current drain of 3 mA. A RAM-resident operating system, called TTBasic, handles data storage and retrieval, analog and digital I/O interfacing, timekeeping, and synchronization. You can also connect the module to a computer for downloading applications. A line of similarly sized mating boards allows the module to access as much as 2M bytes of memory. The operating system augments its Basic interpreter with an in-line symbolic assembler that lets you develop assembly-language subroutines that can be invoked by the main Basic program. $275 (100).

Onset Computer Corp, Box 1030, North Falmouth, MA 02556. Phone (617) 563-2267. TLX 469915.

Circle No 402

DEVELOPMENT SYSTEM

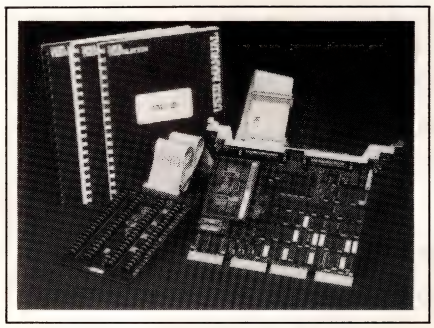
- *DSP-development system uses a µPD77230*
- *32-bit floating-point system achieves 13.5M flops*



The 77230 is a DSP-development system for the IBM PC, PC/XT, PC/AT, and compatibles. The board can do 32-bit floating-point arithmetic by using the NEC µPD77230 advanced signal processor (ASP) to achieve 13.5M flops. Its EDSP workstation software provides a monitor/debugger along with such functions as signal generation, plotting, and menu-driven utilities. The signal generator can generate 15 programmable test signals. The plotter function displays memory contents or files and can do overlays or create dual displays. All of the software functions are provided in a linkable C library for integration in application programs. Communication registers allow the board to perform real-time operations concurrently with the PC. The board's hardware includes a 4k×32-bit program RAM that's expandable to 16k×32 bits; an 8k×32-bit data RAM that's expandable to 32k×32-bits; a Combo/Codec analog I/O interface; an area for A/D and D/A converters; a 4-MHz, serial digital I/O port; a 32-bit, parallel digital I/O port; programmable timing generation; and a hardware benchmark timer. $1995.

Spectrum Signal Processing Inc, 460 Totten Pond Rd, Waltham, MA 02154. Phone (800) 323-1842; in MA, (617) 890-3400.

Circle No 403



QUAD-HEIGHT BOARDS

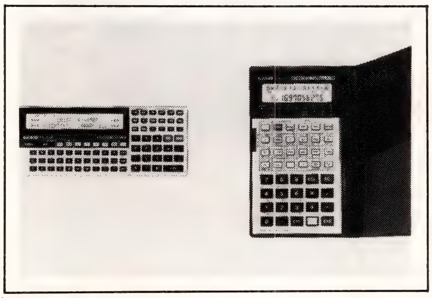
- *Quad-height board family combines multiple functions*
- *Analog and digital interfaces for MicroVAX computers*

The DT2601 Series is a family of multifunction boards for use in MicroVAX 3500, MicroVAX 3600, VAXstation 3500, IVAX 630, and IVAX 630-E systems. Each of these quad-height boards merges the functions provided by two dual-height boards—the DEC AXV11-C analog I/O board and the DEC KWV11-C real-time clock board—with a 16-line digital I/O section. The board's shield and D-shell connectors provide EMI integrity. Each board features analog inputs with 12- or 16-bit resolution, as

many as 16 input channels, data-throughput rates to 125 kHz, programmable gain to 500, and optional simultaneous S/H circuits. Each also has two 12-bit analog output channels with 50-kHz throughput rates and 16 digital I/O lines. Software written for either of the boards can drive any DT2601 Series board. Each board has separate interface registers and interrupt vectors for its analog I/O section, real-time clock, and digital I/O section. From $1995 to $2595.

Data Translation Inc, 100 Locke Dr, Marlboro, MA 01752. Phone (617) 481-3700. TLX 951646.

Circle No 404



POCKET COMPUTERS

- *Two models contain built-in software libraries*
- *Both models provide 2-line displays*

The FX-850P and the FX-5000F are two scientific pocket computers. The FX-850P has 1M bit of ROM containing 116 software utilities, many of which are prompts for input data. Its built-in software library contains math, statistics, physics, and engineering programs. The computer has 8k to 40k bytes of RAM; a 32-character, 2-line display; a formula-storage feature; and 51 direct-use scientific functions. You can program the computer in Basic, and you can connect it to peripherals, such as printers or modems. An RS-232C option lets you send data between the computer and IBM devices. The FX-5000F stores 128 formulas, which can be displayed on a 2-line LCD that prompts you to enter values for a formula. The calculated result and formula are displayed together. You can store 12 user formulas and as many as 10 different user programs in a 675-step memory. FX-850P, $149.95; FX-5000F, $59.95.

Casio Inc, Box 7000, Dover, NJ 07801. Phone (201) 361-5400. TLX 624754.

Circle No 405

I/O CONTROLLER

- *Controls as many as 32 I/O devices*
- *Operates at 9600 baud with 32 users*

The AutoScan board for the VME Bus or the Multibus I controls as many as 32 I/O devices. The board uses a 24-MHz TI TMS99105A μP

and 64k bytes of dual-port static RAM; it has a data-transfer rate of 9600 baud with 32 users. With 16 users, it achieves a 19.2k-baud transfer rate. The single-expansion-slot board provides 32 full-duplex asynchronous or 16 synchronous serial I/O ports. The board provides four RS-232C outputs; these outputs drive 8-port distribution pods at distances as long as 50 ft. The pods may be configured with DB25, DB9, or RJ connectors. When connected to four pods, the board can service 32 devices through four separate cables without daisy chaining. The board acts as a slave device capable of both 8- and 16-bit transfers. Its 64k bytes of RAM may be placed on any 64k-byte boundary within a standard 16M-byte bus address space. The board's control registers, located within an 8-byte block of I/O address space, allow a bus master to start or stop the execution of firmware at any time. Multibus I version, $3595; VME Bus version, $3995.

Ariel Systems Inc, 8545 Arjons Dr, Suite I, San Diego, CA 92126. Phone (619) 549-0134.

Circle No 406

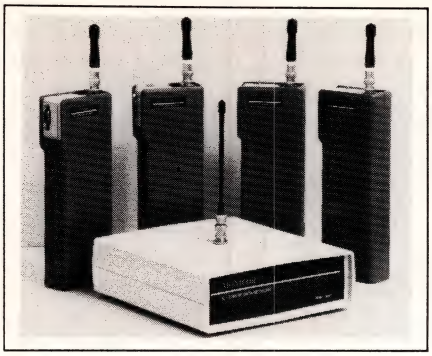
PROJECTION DISPLAY

- *LCD display shows monitor data*
- *Plugs into Macintosh 512, Plus, and SE*

The MacViewFrame is a portable LCD projection device for the Macintosh 512, Plus, and SE computers. It connects to the computer through an adapter inside the Macintosh 512. When placed on a conventional overhead projector, the unit projects and enlarges the computer display. Its cooling fan allows it to operate continuously at >650W without heat damage to the LCD panel. It provides 640×400-pixel resolution and has image-inversion and contrast controls. The unit weighs 4 lbs and measures 15×11×1 in. It plugs into a wall outlet. The display comes in an attaché carrying case along with a video adapter, an interface cable, and a power supply. $1695.

nView Corp, 11835 Canon Blvd, Suite B-107, Newport News, VA 23606. Phone (804) 873-1354.

Circle No 407



WIRELESS LAN

- *RF link connects host computer to as many as 250 peripherals*
- *Provides 2400-bps data rate in 450- to 470-MHz band*

The Monicor System 200 is a wireless LAN for data-collection systems. The IC-210A, a master control unit, connects to a host computer and provides an RF link from the host to as many as 250 different peripheral devices that are connected to portable RF modems. You can wear one of these RF modems (the IC-15), which weighs less than 2 lbs, on your belt. The RF data network can transmit data at user-selectable rates to 9600 baud. RF data transmission takes place at 2400 bps in the 450- to 470-MHz UHF band; the operating range is 1000 ft. IC-15 RF modem, $1895; IC-210A master-control unit, $2495. Delivery, 90 days ARO.

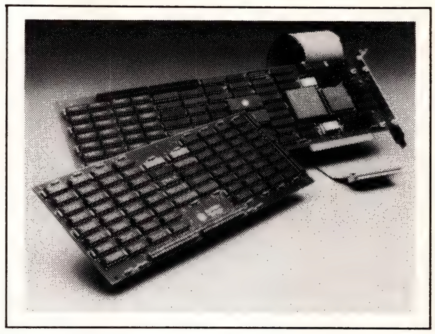
Monicor Electronic Corp, 2964 NW 60th St, Fort Lauderdale, FL 33309. Phone (305) 979-1907.

Circle No 408

CPU BOARD

- *IBM PC/XT-compatible board is based on the 80386 μP*
- *Has 1M byte of 32-bit dynamic RAM*

The Quad386 XT is an enhanced CPU board for the IBM PC/XT or a compatible computer. It contains an 80386 μP running at 16 MHz and has 1M 32-bit words of memory. The memory units consist of 256k-byte dynamic RAMs. You can add 2M or 8M 32-bit words of memory by plugging in daughter cards. The board is socketed for the 80387 and 80287 math coprocessor. The Weitek 1167 floating-point coprocessor is also available on a daughter card. The software includes the Quad Virtual Monitor for memory management, RAM drivers, and print spoolers and drivers; it supports the LIM 4.0 expanded-memory specification.



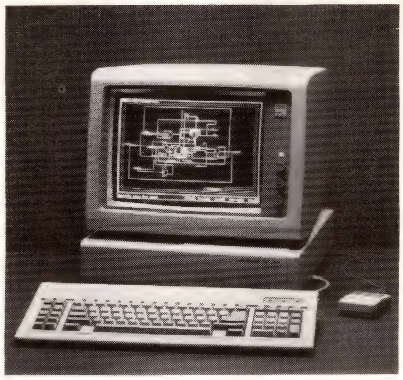
The board has no switches to be set, and it contains a self-running software utility for easy installation. Quad386 XT, $1195; daughter card with 2M 32-bit words of memory, $795.

Quadram, 1 Quad Way, Norcross, GA 30093. Phone (404) 923-6666. TWX 810-766-4915.

Circle No 409

COMPUTER

- *Based on 16-MHz 80386 μP*
- *Designed for network installations*



The Network PC 386 is a PC/AT-compatible computer that uses a 16-MHz 80386 μP. Running MS-DOS, the machine can serve as a desktop workstation in a LAN. It features EGA (enhanced graphics adapter) capability, 1M bytes of RAM, one serial and one parallel port, and a floppy-disk-drive controller. It has four minislots that accept 256k-byte dynamic-RAM modules in single-in-line-memory-module (SIMM) packages. Its 16k-byte cache memory automatically switches word width to handle 8-, 16-, and 32-bit instructions and data transfers. The unit features a real-time clock/calendar with battery backup and can accommodate a half-height 5¼-in. floppy-disk drive. You can obtain a 1.2M-byte floppy-disk drive and a 40M-byte hard disk as options. Three AT-compatible expansion slots are standard. An AT-compatible ROM BIOS lets the computer run AT application programs. Diskless version, $3299 to $3499.

Convergent Technologies, 2700 N First St, San Jose, CA 95134. Phone (408) 434-2848.

Circle No 410

FRAMESTORES

- *Provide real-time image processing for PCs*
- *Allow you to add pseudocolor to monochrome images*

The Synergy framestore for the IBM PC/XT, PC/AT, and compatibles contains a real-time TV-signal image processor. The framestore can digitize the luminance information contained in either an RS-170, NTSC, or PAL TV signal or in a slow-scan video signal, and will

CIRCLE NO 24

store it with 16-bit resolution in its 768×512-pixel video memory. After processing, you can display the image in monochrome or pseudocolor on a standard TV monitor. To ensure a flicker-free display, the framestore preprocesses slow-scan video signals before storing them in the video memory. Onboard image-processing capabilities include convolution, interpolative zooming, signal averaging or weighting to eliminate picture noise, and zonal or feature coloring that uses 256 of a possible 16M colors. You can also compile subframes into a movie sequence of images. You can return processed images to the framestore or transfer them to the PC's disks. A lower-cost version—designated Synapse—has a 512×512-pixel, 8-bit/pixel framestore. Its display format and 15-MHz sampling rate produce square pixels when you use it with 625-line, 50-Hz, interlaced composite video monitors. Both framestores come complete with the vendor's MicroSemper image-processing software. Synergy, £7500; Synapse, £5500.

Synoptics Ltd, 15 The Innovation Centre, Cambridge Science Park, Milton Rd, Cambridge CB4 4BH, UK. Phone (0223) 863223. TLX 81417.

Circle No 411

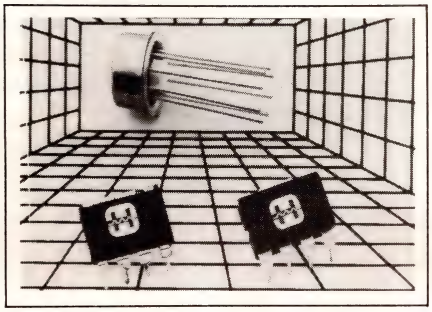
386 COMPUTER

- *Uses an 80386 μP running at 20 MHz*
- *Achieves a 29.5 rating on the Norton SI V3.0 benchmark*

The SIA 386/20 is an 80386-based computer running at 20 MHz. It has a 32-bit mother board and 64k bytes of 30-nsec dynamic cache memory; it achieves a rating of 29.5 on the Norton SI V3.0 benchmark. You can switch the clock speed to 6 MHz; a 24-MHz option is available. The unit contains either a WORM (write once/read many) drive or a hard-disk-drive/floppy-disk-drive controller, a 1.2M-byte floppy-disk drive, 1M byte of memory (expandable to 4M bytes) on the mother board, one serial and one parallel port, and a 101-key PC/AT-style keyboard. The system provides seven channels of DMA, 16 interrupt levels, and three programmable timers. It also has eight I/O slots and an 8-MHz I/O bus that's compatible with the 20-MHz mother board's operation. An optional 80387 math coprocessor is available on a daughter board. An OS/2-compatible BIOS includes setup and diagnostic utilities, which are accessible via hot keys. $3195.

System Integration Associates, 222 E Pearson Ave, Suite 502, Chicago, IL 60611. Phone (312) 440-1275. TLX 4330273.

Circle No 412



LOW-NOISE OP AMPS

- *4 nV/$\sqrt{Hz}$ noise at 100 Hz*
- *10-MHz and 100-MHz bandwidths*

The HA-5101 and HA-5111 are low-noise, high-performance op amps that have identical dc characteristics and noise performance, differing only in ac performance. Both devices have a typical noise-voltage density of only 3.5 nV/$\sqrt{Hz}$ at 1 kHz. The HA-5101 is internally compensated for unity-gain operation; the HA-5111 is uncompensated to achieve higher speed and a minimum stable gain of 10. The HA-5111 combines low-noise performance with a typical slew rate of 50V/µsec and a small-signal gain-bandwidth product of 100 MHz. The fully compensated HA-5101 achieves a typical slew rate of 10V/µsec and a 10-MHz unity-gain bandwidth. Both devices include a typical input-offset voltage of 0.5 mV, a guaranteed minimum output voltage of ±15V into a 600Ω load at a supply voltage of ±18V, and a typical open-loop gain of 120 dB. Pricing in quantities of 100 ranges from $6.75 for the HA7-5111-2 (ceramic DIP, military temperature range) to $4.73 for the HA2-5101-5 (TO-99 package, commercial temperature range).

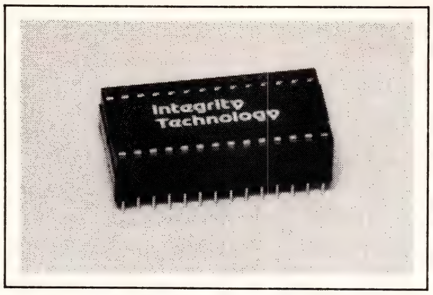
Harris Corp, Semiconductor Sector, Box 883, Melbourne, FL 32901. Phone (305) 724-7800.

Circle No 351

CLOCK/CALENDAR

- *Real-time clock/calendar for IBM PC/XT and PS/2*
- *28-pin DIP module piggybacks ROM BIOS chip*

You can add a clock/calendar function to IBM PS/2 Model 25 computers or to IBM PCs, PC/XTs, and compatibles by plugging this module into any one of the PC's empty ROM sockets or by piggybacking



the ROM BIOS IC. The PC clock/calendar module keeps track of year, month, day, hour, minute, second, and hundredth of second, and automatically adjusts for months with fewer than 31 days and for leap years. The nonreplaceable lithium battery included in the module has a 10-year shelf life and retains 95% of its original output after five years. The module comes with an automated Install program disk and detailed instructions. $33.

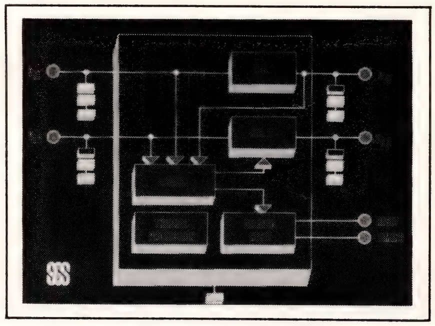
Integrity Technology, 105 Serra Way, Suite 230, Milpitas, CA 95035. Phone (408) 262-8640. TLX 6972396.

Circle No 352

DUAL REGULATORS

- *Circuit contains two 5V regulators and a μP reset*
- *300/400-mA and 100-mA options*

The L4901, L4902, L4903, and L4904 each contain two 5V regulators and a μP reset circuit that help simplify the design of μP systems having backup memory. The L4901 and L4902 provide 5V/300- and 5V/400-mA outputs and are assembled in a 7-lead Heptawatt plastic package. The L4903 and L4904 have two 5V/100-mA outputs and come in plastic miniature DIPs. One output (V_1) supplies power to volatile circuits such as RAM and clock/calendar chips. The other output (V_2) is for circuits that can be turned off. The reset circuit generates a signal for the μP when power is applied or restarted and when the V_1 output falls below a safe value. To allow the use of backup batteries, the leakage current at the V_1 output is < 1 mA.



From $0.65 (10,000).

SGS Semiconductor Corp, 1000 E Bell Rd, Phoenix, AZ 85022. Phone (602) 867-6100. TLX 249976

Circle No 353

HIGH-DENSITY CMOS

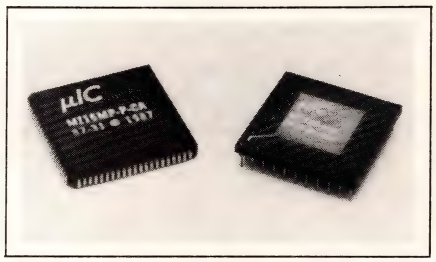
- *Gate densities from 6000 to 104,832*
- *75% utilization is possible*

The HDC (high density CMOS) Series includes 10 arrays having I/O counts from 120 to 512 and available gate counts from 6000 to 104,832.

Fabricated in a 1-µm CMOS process using triple-layer metal, the arrays can achieve 75% utilization. Both wire-bond and tape-automated-bond (TAB) pads are available to allow matching of system I/O requirements. The die size is minimized through the use of programmable triple-layer metal for both signal routing and power distribution on all three levels. The high-end HDC105, for example, provides more than 75,000 usable gates in a die measuring only 486 mils on a side. The primary cell contains eight transistors that can implement two 2-input NAND gates; 1 bit of a 1-,2-, or 4-port RAM; or an 8-bit ROM. Memory cells are available as hard macros in a variety of configurations ranging from 16 words×9 bits to 16k bits of RAM and 32k bits of ROM. Expected prices range from \$0.003 to \$0.008 per usable gate in 16,000- to 100,000-gate densities. Initial packaging will include pin-grid arrays (PGAs) and surface-mount quad flatpacks for lower densities, and multilayer ceramic, cavity-down PGAs for higher densities. Nonrecurring engineering charges will range from \$35,000 for 12,000 usable gates to \$250,000 for more than 75,000 usable gates. Available second quarter of 1988.

Motorola Inc, Technical Information Ctr, Box 52073, Phoenix, AZ 85072. Phone (602) 821-4426.

Circle No 354



16-BIT MULTIPLIER

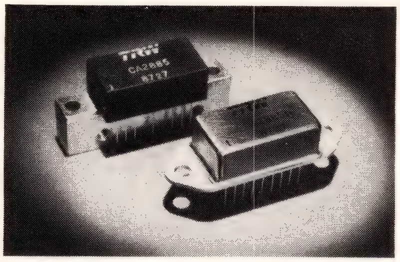
- *Features 50-MHz throughput speed*
- *Provides low power consumption*

The µIC16MP high-speed parallel multiplier produces a 32-bit product from two 16-bit operands in less than 20 nsec. The operands may be either 2's complement, unsigned magnitude, or mixed mode. The device, which operates from a single clock that has separate enables for the x and y registers, can generate products at a rate of 50 MHz. A proprietary pipehold-mode disables the clock enables for both registers and also reduces the current to less than 30 mA at 50 MHz. 50-MHz version in plastic leaded chip carrier (PLCC), \$112; in pin-grid-array (PGA) package, \$136 (100).

Micro Integration Corp, 2833 Junction Ave, Suite 209, San Jose, CA 95134. Phone (800) 541-3425; in CA, (408) 943-0344.

Circle No 355

Continued on pg 227



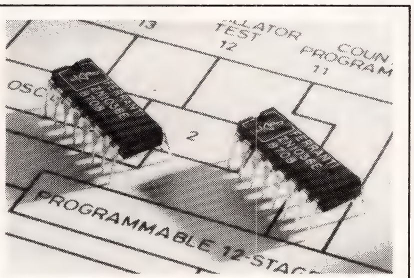
2W RF AMPLIFIERS

- *Offer 18.5-dB gain*
- *40- to 500-MHz bandwidth*

Using an all-gold metallization system, the CA2885 and CA2885H thin-film hybrid amplifiers provide 18.5 dB of linear gain over a bandwidth of 40 to 500 MHz. At a supply voltage of 24V, the devices have a power output of 2W at 1 dB of compression, and their push-pull circuitry keeps distortion low. Typical applications include drivers for VHF/UHF transmitters, fiber-optic drivers for laser diodes or LEDs, and interstage amplifiers in radar and communications systems. High-reliability screening is available for the CA2885H device. CA2885, $50.05; CA2885H, $156.98 (100). Delivery, four to six weeks and 10 to 12 weeks, respectively.

TRW Electronic Components Group, RF Devices Div, 14520 Aviation Blvd, Lawndale, CA 90260. Phone (213) 536-0888.

Circle No 356



TIMER IC

- *Times periods from milliseconds to days*
- *R/C network sets clock period*

Using the ZN1036 programmable timer IC, you can generate time periods ranging from milliseconds to days. The timer has an RC-controlled on-chip oscillator that you can fine-tune with a potentiometer. An internal counter times out the required period according to the device's programming inputs. Complementary output devices indicate when the required period of time has elapsed. You can arrange for the timer to start either at power-on or when it is triggered. Retrigger, power-on reset, and external reset facilities are also provided. You can operate the timer IC from a 5V supply, or, in conjunction with a series resistor, from a higher voltage dc supply. It is available in a 16-pin plastic DIP or an SO-16 package. $1.27 (1000).

Ferranti Electronics Ltd, Fields

New Rd, Chadderton, Oldham OL9 8NP, UK. Phone (0616) 240515. TLX 668038.

Circle No 357

Ferranti Electric Inc, 87 Modular Ave, Commack, NY 11725. Phone (516) 543-0200. TLX 6852104.

Circle No 358

AUDIO SAMPLING ADC

- *Provides 16-bit performance*
- *Features 100-kHz sampling rate*

The ZAD2716 high-performance, 16-bit sampling A/D converter meets the harmonic-distortion, frequency-response, and noise specifications required in professional audio-recording systems. Aimed at audio-digitizing applications, the ADC digitizes an audio signal at a 2× oversampling rate and can digitize two channels at a 50-kHz sampling rate for each channel. Its total harmonic distortion is 0.001% typ over the audio band of 20 Hz to 20 kHz. Its frequency response is stable to within 0.1 dB from dc to 50 kHz, and its rms noise is 30 μV typ. The shielded, integrated module includes a precision A/D converter, a separate sample-and-hold circuit, clock circuitry, a precision reference, and a digital interface. $235 (100).

Analog Solutions, 85 West Tasman Dr, San Jose, CA 95134. Phone (408) 433-1900.

Circle No 359

MEMORY CONTROLLER

- *Controls 32-bit cache memory*
- *Supports 20-MHz 80386-based Compaq desktop computer*

The 82385 supports the Compaq 80386-based, 20-MHz desktop computer as well as other similar PCs. Compared with alternative cache subsystems, the 20-MHz cache-control device offers significant performance improvement for computers using the 80386 μP, according to the manufacturer. The device's interface to the 80386 μP and to the system bus is software transparent, requiring no modifications to existing software. The device can store 32k bytes of the most frequently used code and data from the full 80386 physical-address range of 4G bytes. The controller comes in a 132-pin pin-grid-array package. $125 (10,000).

Intel Corp, Literature Dept #W394, Box 58065, Santa Clara, CA

95052. Phone (800) 548-4725; in OR, (916) 351-6289.

Circle No 360

DRIVER/RECEIVER PAIR

- *Provides 100-psec rise and fall times*
- *Supports data rates of 3G bps*

The TQ6330 pin-driver and the TQ6331 line receiver achieve 100-psec rise and fall times, and support data rates of 3G bps. The inputs are ECL compatible, and you can control the output-voltage levels between ±3V to interface with ECL, TTL, or CMOS devices. The outputs typically produce a voltage swing as high as 4V into 50Ω. When not terminated into a 50Ω load, the output voltage is adjustable between 5 and −3V, providing voltage swings as high as 8V. The units come in 44-pin multilayer ceramic (MLC) packages. Either the TQ6330 or TQ6331, in die form, $98; in MLC packages, $159.

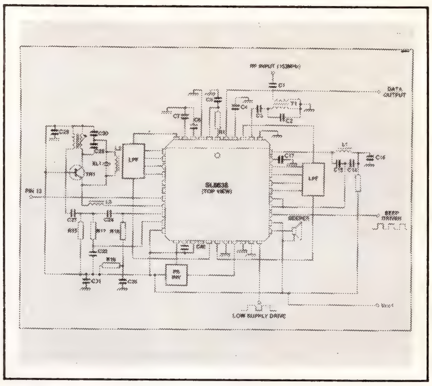
TriQuint Semiconductor, Group 700, Box 4935, Beaverton, OR 97075. Phone (503) 629-3535.

Circle No 361

RADIO IC

- *Receives broadcast frequencies as high as 200 MHz*
- *Operates at data rates as high as 1200 bps*

The SL6638 is a single-chip radio receiver designed for battery-powered time and data-paging equipment that operates at broadcast frequencies as high as 200 MHz. It has a typical input sensitivity of 200 nV, and an operational power consumption of 4 mW. In standby mode, it consumes only 260 μW. The radio is based on a direct-conversion receiver and is suitable for reception of data at rates as high as 1200 bps.



The device includes a beeper/LED-driver output, and a low-battery alarm indicator. It is packaged in a 44-lead chip carrier and costs £6.25 (1000).

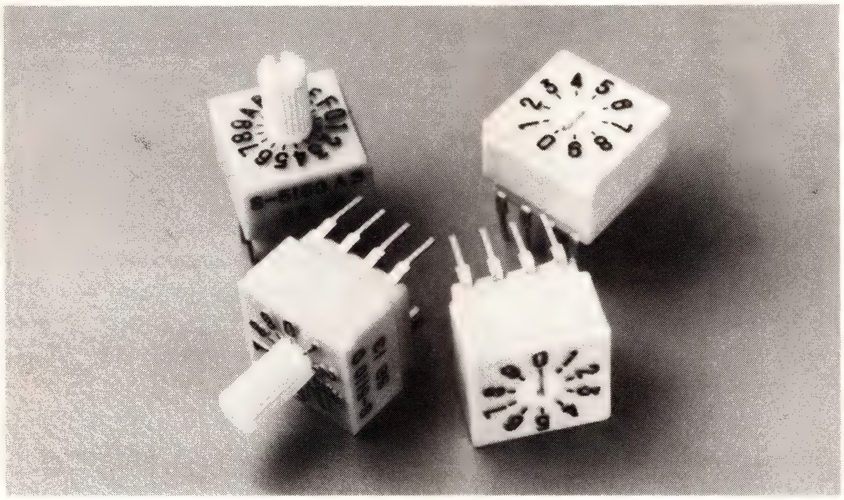
Plessey Semiconductors Ltd, Cheney Manor, Swindon, Wiltshire SN2 2QW, UK. Phone (0793) 36251. TLX 449637.

Circle No 362

Plessey Semiconductors, 9 Parker, Irvine, CA 92718. Phone (714) 472-0303.

Circle No 363

COMPONENTS & POWER SUPPLIES



ROTARY SWITCHES

- *Sealed for heat and contamination resistance*
- *Available in 10- or 16-position versions*

Each S-5000 Series binary-coded DIP rotary switch is sealed with an O-ring for heat and contamination resistance. The devices' pin configurations are compatible with conventional rocker or piano-key type DIP switches; as a result, you can use the devices to replace such switches without changing the pc-board pattern. The devices' contacts switch 4V dc Hz at 100 mA and carry 50V dc (open) at 100 mA (closed). The units have mechanical lives of 10,000 steps and come in 10- or 16-position versions. Options include top or side adjustment, flush or knob adjustment, hexadecimal or binary coding, real or complementary coding, and resistor or diode arrays. From $2.80 (500).

Mepcopal, 11468 Sorrento Valley Rd, San Diego, CA 92121. Phone (619) 453-0332.

Circle No 364

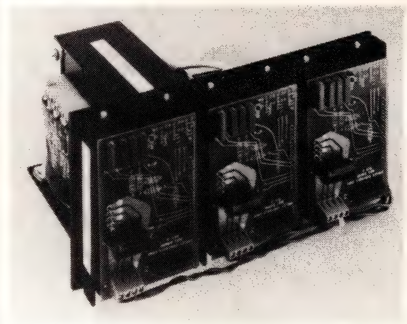
CHIP RESISTORS

- *Feature tight dimensional tolerances*
- *Available in two styles*

CR Series chip resistors feature electrodes with ±0.15-mm dimensional tolerances that minimize the likelihood of component tombstoning. The resistors come in both 1206- and 0805-style packages. CR1206 versions offer a resistance range of 10Ω to 1 MΩ and feature a 100-mW power rating at 70°C. You can obtain CR0805 devices with resistance values of 10Ω to 1 MΩ and 125-mW power ratings at 70°C. The resistors' operating-temperature range spans −55 to +125°C. The chip resistors are available in paper tape-and-reel packages for automated assembly, but you can special order the resistors in embossed-tape packages. From $.023 (5000). Delivery, 10 weeks ARO.

Bourns Inc, 1200 Columbia Ave, Riverside, CA 92507. Phone (714) 781-5500. TLX 676423.

Circle No 365



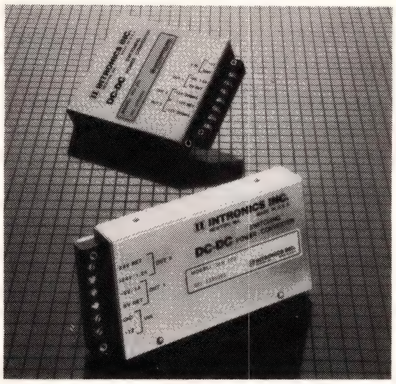
MOTOR DRIVES

- *Provide servomotor drive power for as many as three axes*
- *Accommodate a wide choice of PWM amplifier types*

Each Series 600 subsystem consists of as many as three complete servomotor drive channels combined with a power supply. The subsystems accommodate a wide range of PWM (pulse-width-modulated) amplifier types. Amplifiers compatible with the 600 chassis provide current ratings between ±2 and ±10A at output voltages of ±20 to ±150V. All the servoamplifiers are protected against short circuit, overcurrent, undervoltage, overvoltage, and excessive temperatures. You can order the Series 600 chassis with different amplifiers for each axis. The amplifier modules provide 4-quadrant operation and a 1-kHz bandwidth. From $450 for a single-axis version equipped with an amplifier that delivers 100W continuous. Delivery, six weeks ARO.

Copley Controls Corp, 375 Elliot St, Newton, MA 02164. Phone (617) 965-2410. TLX 285957.

Circle No 366



DC/DC CONVERTERS

- *Available in single-, dual-, and triple-output versions*
- *Provide outputs to 60W*

DCM Series nonisolated power converters accept 11 to 16V dc inputs and provide 12 to 60W outputs. You can obtain single-, dual- and triple-output versions. The DCM 101, which mounts on a pc board, and the DCM 103 provide a 5V output regulated to +5, −0%; the DCM 108 features a 12V dc output. The DCM 102, DCM 104, and DCM 107 models feature 5 and 24V dc outputs and provide 30 to 60W power levels. The DCM 106 provides 5 and 12V dc outputs. The DCM 105 outputs 5 and ±12V dc. All units operate over 0 to 50°C and feature overvoltage and short-circuit protection. They have an 80% min efficiency spec. The converters feature 6-sided shielding, and you can mount them on a chassis. Termination occurs via a terminal block. $57 to $187 (100).

Intronics Inc, 57 Chapel St, Newton, MA 02158. Phone (617) 964-4000. TLX 200095.

Circle No 367

MOSFET MODULES

- *Come with serial or parallel internal connections*
- *Have isolation voltage rating of 2500V*

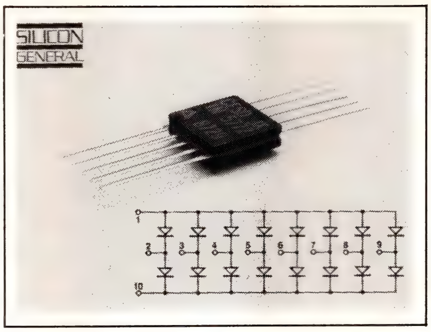
SKM Series power MOSFET modules are housed in packages that accommodate several devices connected in series or parallel. An SKM module will replace as many as six TO-3 power MOSFETs. The SKM-181 is rated at 30A/800V. The SKM-151-F, rated at 50A/500V, features an integrated fast-recovery diode. The modules' electrical circuits are isolated from the heat-transferring surface and have an isolation rating of 2500V; you can thus mount more than one module on a single heat sink. Because each module's electrical connections are on the top of the package, you can easily connect the devices to bus bars. The modules feature large clearance and creepage distances. SKM-151-F, $70 (50).

Semikron Inc, Box 66, Hudson, NH 03051. Phone (800) 258-1308; in NH, (603) 883-8102. TLX 6711011.

Circle No 368

DIODE ARRAY

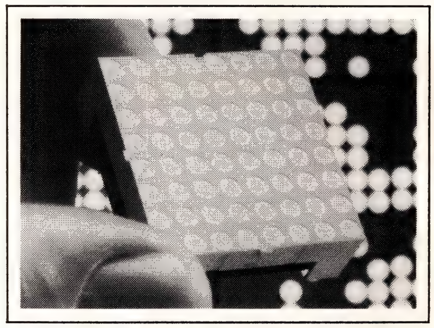
- *Meets MIL-S-19500/474 requirements*
- *Has 10-nsec switching speeds*



The 1N5772 16-diode array features eight common cathodes and eight common anodes and is qualified to JANTXV, JANTX, and JAN processing levels. Each diode can sustain a minimum breakdown voltage of 60V and a minimum current of 500 mA. The device meets all MIL-S-19500/474 requirements and is suitable for use in high-speed military applications. It has a switching speed of 10 nsec max, operates from −55 to +150°C, and comes in a 16-pin ceramic flat pack. $21 (100).

Silicon General Inc, 11861 Western Ave, Garden Grove, CA 92641. Phone (714) 898-8121. TWX 910-596-1804.

Circle No 369



DISPLAYS

- *Stackable to produce dot-matrix displays of any shape or size*
- *Include drive electronics*

The PD1165 and the PD1167 are 8×8-pixel dot-matrix displays that you can stack together to create flat-panel displays of any shape or size. The PD1165 produces an orange display, and the PD1167 has a green display. The units measure 30×30 mm and include onboard CMOS logic for multiplexing and driving; it also provides an 8×8-bit RAM and an 8-bit TTL-compatible control interface. You can add an external ROM to store special character fonts, symbols, or graphics. In addition to using the units control individual display pixels, you can program them to produce one of nine different display intensities; to initiate blanking, blinking, and test functions; and clear the display memory. The displays have an operating range of −20 to +70°C and a 75° viewing angle. PD1165, $27; PD1167, $30 (1000).

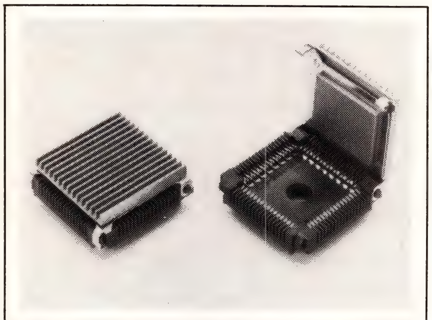
Siemens AG, Zentralstelle für In-

formation, Postfach 103, 8000 Munich 1, West Germany. Phone (089) 2340. TLX 5210025.

Circle No 370

Siemens Components Inc, 186 Wood Ave S, Iselin, NJ 08830. Phone (201) 321-4520.

Circle No 371



LCC SOCKETS

- *Available with or without aluminum heat sinks*
- *150°C max operating range*

These sockets can accommodate 68-pin LCC devices in actual-use applications—not just in burn-in service. They are available with or without aluminum heat sinks. Versions are available to mount either JEDEC Type A or Type B ceramic leadless chip carriers. The body material is composed of polyphenylene sulfide, and the cover material is made of stainless steel. The beryllium copper contacts feature gold-over-nickel plating. The sockets can withstand 150°C operating temperatures. $4.01 (1000). Delivery, stock to six weeks ARO.

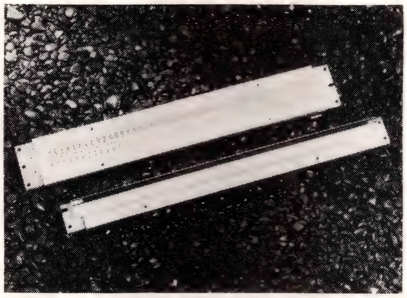
Nepenthe, 2471 E Bayshore Rd, Palo Alto, CA 94303. Phone (415) 856-9332.

Circle No 372

PRINTHEADS

- *Offer 12-in. print widths*
- *Focus elements individually*

The RLH3012 and RLH4812 LED-based printheads offer 12-in. print widths and run at 300 and 480 dots/in., respectively. The units utilize LED bars based on GaAsP technol-

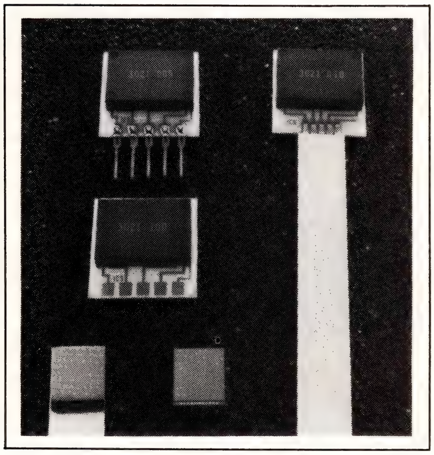


ogy, with 64 LEDs/bar in the 300-dot/in. models and 128 LEDs/bar in the 480-dot/in. versions. While laser printheads emit light from a single, fixed source, these printheads focus each element at a specific location to provide better registration. In the 300-dot/in. units, one, two, or four data-input lines are available with data-transfer times running from

128 to 512 μsec/line at a clock frequency of 7 MHz. In the 480-dot/in. models, two, four, or eight data-input lines are available with data-transfer times running from 100 to 400 μsec/line at a 7-MHz clock frequency. RLH3012, $2500; RLH4812, $4000. Delivery, eight weeks ARO.

Rohm Corp, Box 19515, Irvine, CA 92713. Phone (714) 855-2131. TWX 910-595-1721.

Circle No 373



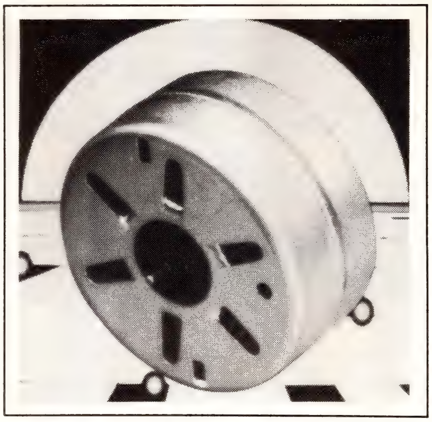
ACCELEROMETER

- *Monitors acceleration, vibration, and shock*
- *Measures only 7.9×7.3 mm*

Model 3021 monitors acceleration, vibration, and shock. It measures 7.9×7.3-mm and is well suited to applications characterized by limited sensor-mounting area. Operating at 5V or 1.5 mA, the piezoresistive, full-bridge accelerometer provides true dc response and achieves full-scale sensitivities of more than 50 mV. The sensor has a ±5 to ±100g operating range, a 20× overrange capability, built-in overforce stops, and a 0.707 damping factor (alternate damping ratios are available). Its damping temperature dependence is controlled to better than ±10% over the entire operating range. $87.

IC Sensors Inc, 1701 McCarthy Blvd, Milpitas, CA 95035. Phone (408) 432-1800.

Circle No 374



STEPPER MOTORS

- *Tested to run continuously for over three years at 400 Hz*
- *Feature maintenance-free self-lubricating bearings*

The D34L61MUD Series 15° full-step-angle, 2- and 4-phase stepper motors feature maintenance-free self-lubricating bronze bearings. The motors have been tested to run continuously for more than three years at 400 Hz. The 2-phase version uses a 2-part, 48-pole stator that surrounds the toroidal coil with two separate single windings for bipolar operation. The 4-phase motor has double windings for unipolar operation. The motors are available to operate on 6, 12, or 24V dc. Both versions feature 24 steps/revolution in full step. The rotation direction is reversible. Both versions are available either with plain shafts or with a pinion option for use with a wide variety of gearboxes. $27.68 for the 2-phase unit.

Stock Drive Products, 2101 Jericho Tpk, New Hyde Park, NY 11040. Phone (516) 328-3330.

Circle No 375

ATTENUATORS

- *Operate over dc to 1000 MHz*
- *±1% step-to-step accuracy*

The 50Ω Model 5L80P and the 75Ω Model 7L80P pc-board-mountable, latching programmable attenuators operate over dc to 1000 MHz and attenuate to 80 dB in 1-dB steps. The devices' structure consists of

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Frank W. Kussy, *Consultant Engineer, Randallstown, Maryland*

Jack L. Warren, *Chrysler Corporation, Highland Park, Michigan*

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—INSPEC SCIENCE ABSTRACTS (The Institution of Electrical Engineers)

1986 408 pp., illus. $69.75

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Michael P. Perry, *General Electric Company, Schenectady, New York*

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1985 256 pp., illus. $49.75

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Colonel W. T. McLyman, *K. G. Magnetics, Inc., South Pasadena, California*

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—Current Engineering Practice

1988 496 pp. (tent.), illus. $55.00

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1987 132 pp., illus. $495.00

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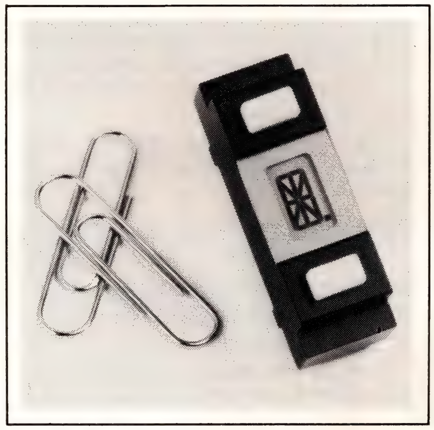
four cells with 1-, 2-, 4-, and 8-dB values, as well as three cells with 10-, 20-, and 40-dB values. The binary cells provide 0- to 10-dB attenuation in 1-dB steps, and the 10- to 40-dB cells provide 0- to 70-dB attenuation in 10-dB steps. The accuracy specs are ±0.5 dB to 500 MHz and ±1 dB to 1000 MHz. The step-to-step accuracy is ±0.25 dB to 500 MHz and ±0.5 dB to 1000 MHz. The operating range spans −18 to 71°C, and the insertion loss equals 1.2 dB max. $145. Delivery, stock to six weeks ARO.

Trilithic Inc, 6840 Winona Dr, Indianapolis, IN 46236. Phone (317) 823-4719.

Circle No 376



SWITCH

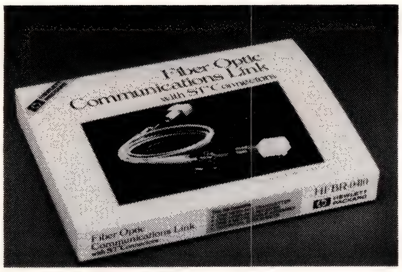
- *Combines display and switch functions in a single module*
- *Operates from a 5V supply*

The SST-1000 solid-state device uses a single LSI chip to combine alphanumeric-display and thumbwheel-switch functions in a single module. Each module contains a single-character alphanumeric LCD, up/down pushbuttons, and a low-power CMOS controller chip. The switch operates from a 5V supply and is TTL compatible. It communicates with the host processor via a RAM-like interface. Programmable features include hex/decimal/octal/binary thumbwheel modes, read/write/display thumbwheel settings, write/display ASCII characters,

flash/test/blank display, decimal-point on/off, and thumbwheel-lock on/off. $12.50 (100).

Microdot Graphics Inc, American Control Technology Div, Box 585, West Dundee, IL 60118. Phone (312) 426-6780.

Circle No 377



OPTICAL MODULES

- *Designed for 3-km links*
- *Feature 5-million-hour min MTBF*

HFBR-X400 fiber-optic transmitter and receiver modules mate directly with both AT&T's ST connector and with bayonet-style connectors from a variety of manufacturers. You can use them in computer-communication channels, industrial systems, and data-communication links of 3 km or less. The modules interface with 62.5/125-, 50/125-, and 100/140-μm multimode fibers. The module line includes the HFBR-1412, a standard transmitter; the HFBR-1414, a high-power transmitter; the HFBR-2412, a 5M-baud receiver; and the HFBR-2414, a 25-MHz analog receiver. The transmitters and receivers come in autoinsertable and wave-solderable dual-in-line packages. When operating at 40°C, the units feature an MTBF in excess of 5 million hours. To ease the evaluation process, you can order a kit containing a transmitter, receiver, and 3m of cable with connectors. Modules, $12.50 to $23 (1000); kit (HFBR-0410), 49.95.

Hewlett-Packard Co, 1820 Embarcadero Rd, Palo Alto, CA. Phone local office.

Circle No 378

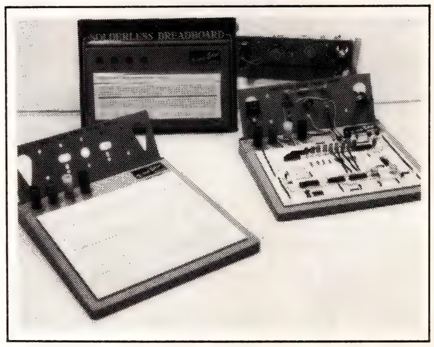
POWER SWITCHES

- *Designed for use in harsh environments*
- *Connections insulated against accidental actuation*

Sealed to IP 65 specifications, Series 22 power switches are designed for harsh environments where dust, oil, grease, or water can cause problems. The ruggedized shock-proof case resists chemicals and meets IP 20 standards. The rear connections are completely insulated against inadvertent actuation. The self-cleaning, double-break, snap-action switch system offers a choice of three contact configurations—two NC, two NO, or one of each. Maintained contacts with switch-mode indication or momentary-action contacts are available. The contacts in the series are rated for 12V ac at 50 mA min and 380V ac at 10 mA max. Dielectric strength between all terminals and ground equals 2000V ac. All switches are UL, CSA, VDE, and SEV approved. From $6.25. Delivery, four to six weeks ARO.

EAO Switch Corp, 198 Pepe's Farm Rd, Milford, CT 06460. Phone (203) 877-4577.

Circle No 379



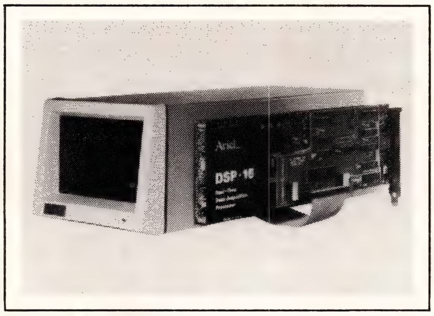
BREADBOARDS

- *Accommodate nonstandard parts*
- *Contacts rated for 10,000 in-out insertions*

X-tra Edge-style solderless breadboards feature an extra multiuse edge panel for organizing and mounting components that don't fit into DIP-spaced breadboard socket connections. The boards come in four models that offer from 810 to 2940 tie-points. Each model includes an area containing both distribution and terminal strips that accommodate all DIP sizes, lead components, and wire gauges of 20 to 29 AWG. The phosphor bronze, nickel-plated contacts have a 3-mΩ initial contact resistance and have a min 10,000 in-out-cycle lifetime rating. Four multipurpose binding posts are standard on each breadboard. $16.95 to $59.95.

Chenesko Products Inc, 21 Maple St, Centereach, NY 11720. Phone (516) 736-7977.

Circle No 380



INTERFACE

- *Uses PC to perform 50-kHz sampling of two analog channels*
- *Available with hard disks as large as 250M bytes*

The SDI signal-to-disk interface allows real-time acquisition, direct-to-disk recording, and processing of two channels of data at a 50-kHz rate. The unit consists of software and a PC-bus-compatible board that contains signal-conditioning circuits, a 16-bit ADC, and a SCSI interface. Its onboard processor relieves the PC's μP of the need to control data flow to and from disk, making possible the high data-transfer rate. A special disk operating system, which coexists with MS-DOS, controls operations related to SCSI data-storage devices. You can obtain the interface system with either 50M- or 250M-byte internal or external SCSI-interfaced hard drives; the SCSI bus and the software both support as many as seven drives. From $3495.

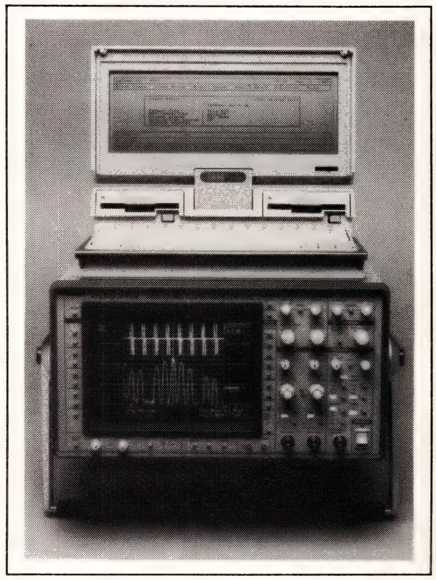
Ariel Corp, 110 Greene St, Suite 404, New York, NY 10012. Phone (212) 925-4155. TLX 4997279.

Circle No 386

DIGITAL SCOPE

- *Adds portable mass storage to the vendor's DSOs*
- *Includes IBM laptop PC or works with desktop PC*

The MS01 mass-storage package adds the laptop IBM PC Convertible's floppy-disk storage capacity—two 720k-byte 3½-in. microfloppy-disk drives—to LeCroy's 9400 digital storage oscilloscope (DSO). The MS01, which includes the IBM PC Convertible, is suitable for storage of full, partial, or segmented scope waveforms in applications that require portability. The MS02 is suitable for laboratory use and lets you store waveforms on disk in your desktop IBM PC or compatible computer. The MS01's DSO communicates with its IBM PC Convertible at speeds to 220k bytes/sec. The MS02's DSO will communicate with your desktop machine at speeds to 400k bytes, provided your computer is sufficiently fast and employs a National Instruments' IEEE-488 interface board. MS01, $2900; MS02, $600. Delivery, eight weeks ARO.



LeCroy, 700 Chestnut Ridge Rd, Chestnut Ridge, NY 10977. Phone (914) 578-6084.

Circle No 387

LOGIC ANALYZER

- *Hosted by IBM PC or compatible computer*
- *Includes 8-bit μP pod*

The PA480 logic analyzer consists of a single board for the IBM PC bus and an external logic pod. The basic board supports 48 channels and has 4095 words of memory. You can clock it with an external 25-MHz clock or with an internal 10-MHz clock. The analyzer lets you define 16 48-bit trigger words in which each bit can be a one, a zero, or a "don't care." You can also select 16 trigger-delay values. In addition to a 48-channel, general-purpose pod, the vendor offers disassembler pods for the following μPs: 8086, 8088, 68000, 68010, Z80, 8085, 6502, 6801, and 6303. With a Hercules graphics adapter, the unit can display 16 waveforms; with an IBM EGA, CGA, or similar adapter, it can display eight waveforms. It can also display data in binary, octal, hexadecimal or decimal-ASCII formats. $2090 for 8-bit μPs; $2290 for 16-bit μPs.

NCI, 6438 University Dr, Huntsville, AL 35086. Phone (205) 837-6677.

Circle No 388

EMULATOR

- *Connects to IBM PC or compatible computer*
- *Supports 8051 family*

The in-circuit emulators in the MicroIce family provide the same features as the vendor's earlier MetaIce units, but at approximately half the cost. MicroIce emulators connect to IBM PCs and compatible computers; they provide development-system capabilities such as support of high-level languages, symbolic debugging, real-time and transparent emulation at clock rates as high as 16 MHz, single-line disassembly, a 2k-byte trace buffer, 16 break and trace triggers, 16k bytes of program memory, and 16k bytes of external data memory. The symbolic debugging capability supports Intel OMF and hex formats, as well as formats used by MetaLink, Enertec, Microtec Research, IAR Systems, and Archimedes. Supported μPs include 8031, 80C31, 8032, 8344, 80C252, 80C32, 80C154, 8053, 8753, 8751, 8752, 87C51, 8051, 80C51, 8052, 80C52, and 83C154. $1495 to $2195; power supply, $75; 64k bytes of program memory and 64k bytes of data memory, $300.

MetaLink Corp, Box 1329, Chandler, AZ 85244. Phone (602) 926-0797.

Circle No 389

DEVELOPMENT SYSTEM

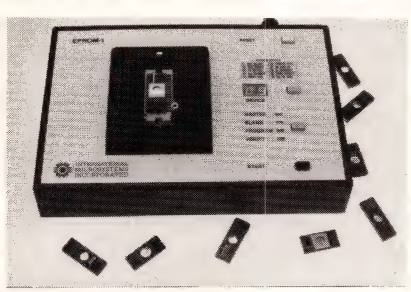
- *Software runs on Apple Macintosh PCs*
- *Supports 22 8- and 16-bit μPs*

This universal 8/16-bit cross-development kit includes a table-driven crossassembler furnished on an 800k-byte Macintosh-formatted microfloppy disk, and one of the vendor's Memulator in-circuit EPROM emulators that you connect to a Macintosh modem port, using an optional adapter cable. Two versions of the EPROM emulator are available. The Memulator II works

with systems whose ROM is 1 byte wide; the Memulator 16 is for systems that use pairs of ROMs organized as 16-bit words. Both units have 150-nsec access times and emulate JEDEC-standard devices in the 2716 to 27256 Series. The software runs on any Macintosh having 512k bytes of RAM or more. Among the 22 emulated processors are the 8086, 8088, Z80, 64180, 6809, and 6502. The system supports processors having an address space of 24 or fewer bits, as well as the following industry-standard data formats: Intel hex, Motorola S-record, and straight binary. Most EPROM programmers accept files in these formats. With Memulator II, $725; with Memulator 16, $1275.

Memocom, 1920 Arbor Creek Dr, Carrollton, TX 75010. Phone (214) 446-9906.

Circle No 390



EPROM PROGRAMMER

- *Programs 1M-bit devices*
- *Supports five types of programmable µPs*

According to the manufacturer, the EPROM-1-128K programs all configurations of 1M-bit EPROMs. These configurations include 28-pin devices with byte-wide data and paged addressing, 32-pin devices with byte-wide data and nonpaged addressing, and 40-pin devices organized in 16-bit words. You need an adapter for 32- and 40-pin devices. You can use the programmer to duplicate a master device, or you can download data via an RS-232C port. The vendor includes software for transferring files from an MS-DOS- or PC-DOS-based personal computer. Before attempting to program a device, the programmer performs tests to make sure that you've correctly inserted the device into its socket. $595; adapters for 32- and 40-pin devices, $125.

International Microsystems Inc, 790 E Arques Ave, Sunnyvale, CA 94086. Phone (408) 245-7180. TWX 650-258-8135.

Circle No 391

80C196 EMULATOR

- *Runs under MS-DOS 3*
- *Supports device speed of 12 MHz*

The Ice-196PC PC-hosted in-circuit emulator supports the 16-bit CHMOS 80C196 microcontroller. It runs on an IBM PC/XT, PC/AT, or compatible computer under MS-DOS 3.0 or higher, and it's compatible with the vendor's MCS-96 programming languages, including ASM-96 as well as C-96 and PL/M-96. Symbolic debugging with a source-code display lets you debug, using high-level language statements, thus giving you the option of not debugging at the assembly-language level. The emulator supports transparent 80C196 emulation at device operating speeds as high as 12 MHz. Using an optional crystal power accessory (CPA) and the emulator's mappable memory, you can develop and debug application software before your target hardware becomes available. The emulator includes 64k bytes of zero-wait-state memory mappable in 4k-byte increments, a 2k-entry trace buffer, and three hardware breakpoints or one range break. With CPA, $2995; without CPA, $2495.

Intel Corp, Box 58065, Santa Clara, CA 95052. Phone (408) 987-8080.

Circle No 392

NEW PRODUCTS

CAE & SOFTWARE DEVELOPMENT TOOLS

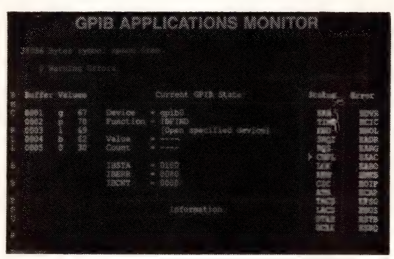
FILE REPAIRER

- *Analyzes and repairs damaged dBASE files*
- *Provides search and editing facilities*

dSALVAGE uses a variety of automatic recovery procedures to diagnose and repair damaged dBASE files. It's menu driven and can handle any type of dBASE file (not just the DBF files). A query-by-example feature lets you search for specific items in the files, and a recovery feature lets you restore files that have been deleted with the Zap command. A multimode screen editor provides complete block handling and automatic data realignment, under manual control, to help you repair damaged files and reinsert lost or garbled data. $99.95.

Comtech Publishing Ltd, 5095 Murphy Canyon Rd, Suite 200, San Diego, CA 92123. Phone (619) 277-1973.

Circle No 393



IEEE-488 DEVICE DRIVER

- *Results in easier-to-write instrument-control software*
- *Provides debugging facilities*

The NI-488 MS-DOS device-driver software package helps you develop instrument-control software on IBM PC and PS/2 computers and compatibles. The enhancements to the package support Version 4 of Microsoft's QuickBasic. They also include an applications monitor that gives you program-tracing facilities and a special interrupt service request using the Basic ON PEN statement. This feature eliminates the need for continuous polling to capture instrument service requests. The package includes a QuickBasic language-interface library and a BasicA library, both of which are designed specifically to aid in the development of instrument-control software. You can instruct the monitor to install breakpoints that show the details of the most recently executed IEEE-488 call on a pop-up screen. The display can also show you a listing of as many as 255 of the preceding IEEE-488 calls. This feature eliminates the need to insert debugging statements in the instrument-control source code. The package is included with the vendor's GPIB-PCII ($395), GPIB-PCIIA-2 ($495), and MC-GPIB ($495) interface boards; current users of these products may upgrade to the new package at nominal cost.

National Instruments, 12109 Technology Blvd, Austin, TX 78727. Phone (800) 531-4742; in TX, (800) 433-3488. TLX 756737.

Circle No 394

NEURAL-NET TUTORIAL

- *Lets you study the operation of an associative memory*
- *Emulates networks with as many as 1000 neurons*

Netwurkz introduces you to associative-memory concepts and their implementation by means of a neural model. These models consist of processing elements, analogous to neurons, that use rules such as the sum of products to produce an output from multiple inputs. The output of one neuron can form part of the input to other neurons to produce an aggregate (a neural net), which can learn complex patterns and recall patterns correctly, even when the

input is not an exact match. The associative-memory demo comes with a PL/D compiler that lets you add new Data statements in the demo or modify existing statements. The example uses approximately 50 neurons, and you can expand the net to a maximum of 1000 neurons. To run the program, you'll need an IBM PC, PC/XT, PC/AT, or a compatible computer that's equipped with at least 192k bytes of RAM and MS-DOS version 2.0 or later. Netwurkz, $79.95; PL/D compiler, $124.95; both devices, $154.95.

DAIR Computer Systems, 3440 Kenneth Dr, Palo Alto, CA 94303. Phone (415) 494-7081.

Circle No 395

MATH SOFTWARE

- *Provides an equation solver and expression analyzer*
- *Includes curve-fitting and matrix utilities*

The MathMate integrated mathematical-software package runs on the IBM PC and compatibles. Its menus let you select the operations you wish to perform, and provide context-sensitive, on-line help. The program automatically checks your input and reports any detected errors. A spreadsheet interface lets you solve simultaneous linear equations with as many as 26 variables. The program also solves polynomial equations to the ninth order and finds both the real and imaginary roots. Its statistical facilities let you use all the standard calculator operations and, in addition, provide hot-key initiation of routines to find the mean, rms, maximum deviation, minimum deviation, average deviation, mode, median, or standard deviation of as many as 512 statistical data elements. When using the programmed mode, you can create as many as 512 program steps to handle as many as 128 user-defined variables. To run the program, you need a PC, PC/XT, PC/AT, or compatible with at least 256k bytes of RAM (640k bytes is recommended), a hard disk and one floppy-disk drive, and a CGA (color graphics adaptor) or EGA (enhanced graphics adaptor) board. $99.95.

MCAE Technologies Inc, 3474 Nova Scotia Ave, San Jose, CA 95124. Phone (408) 371-6095.

Circle No 396

SEARCH SOFTWARE

- *Can search rapidly through more than 1,000,000 objects*
- *Compatible with CD-ROM and WORM optical-disk drives*

The SearchExpress software package can rapidly search through a large number of objects (text documents, images, and database records) to find objects of interest. Its features include compatibility with CD-ROM and WORM laser-disk drives; the ability to perform Boolean selection and to rank objects according to the frequency of occurrence of the search word(s) within each object; the ability to search for objects that have similar content; and hypertext, which allows you to link related objects for recall with a single keystroke. The package allows as many as 255 user-definable data fields and provides pull-down menus, beginner and expert operation modes, and on-screen help. You can use the package as a stand-alone search utility or can incorporate it into other, larger, systems. The package runs under the MS-DOS operating system. Three versions are available, priced according to the number of objects they can search: for 1000 objects, $179; for 1,000,000 objects, $349; for WORM optical databases, $695.

Executive Technologies Inc, 2120 16th Ave S, Birmingham, AL 35205. Phone (205) 933-5494.

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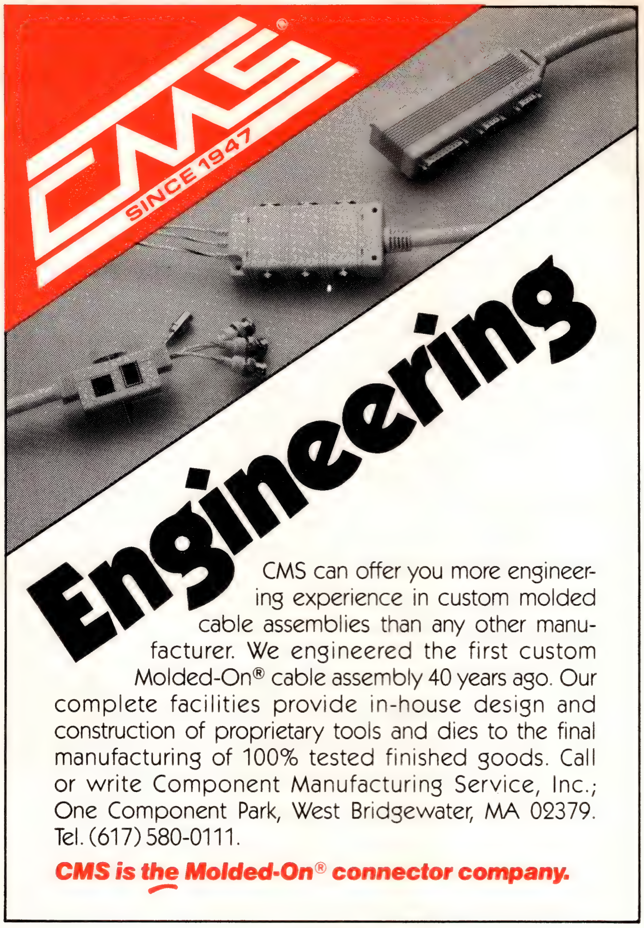
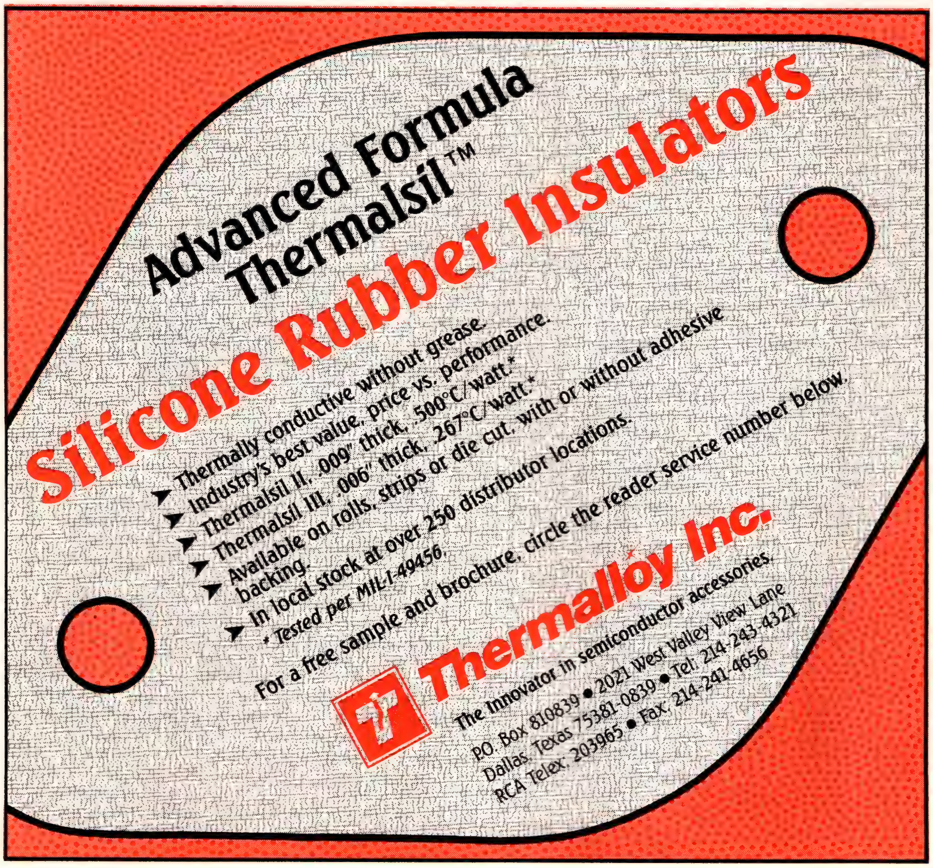


CIRCLE NO 20



CIRCLE NO 47

SERIAL DATA ANALYZER

- *Lets you capture and analyze all traffic on a serial link*
- *Has menu-driven user interface that simplifies operation*

The PCDA software package runs on an IBM PC or compatible and lets you capture and display serial-communications link traffic. The program captures and displays each byte as well as error codes and control-line information that passes between two communicating stations. You can display the data in 8-bit ASCII format or in hexadecimal format; further, you can display data originating at one station in normal intensity and data originating at the other station in high intensity. The software lets you store communications-setup parameters in disk files. All monitored data is initially stored in a 64k-byte buffer that you can transfer to a disk for later recall and examination. The program's Browse mode opens a window into the buffer that you can move forward or backward over the buffer's contents. To run the package, your computer must have at least 128k bytes of RAM, one serial port (two are recommended), and DOS version 2.0 or higher. $95.

Triple C Software Inc, 800 W Oakland Park Blvd, Suite 217, Fort Lauderdale, FL 33311. Phone (305) 564-8011.

Circle No 398

CROSS-DEVELOPER

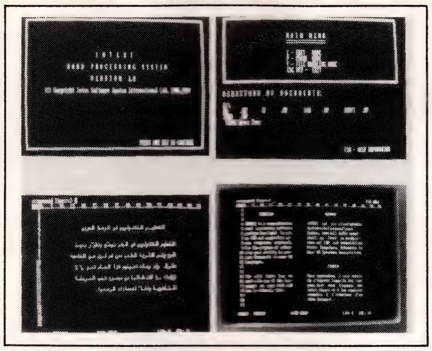
- *Has editor, assembler, and EPROM emulator*
- *Has table-driven crossassembler*

The ST Universal Cross-Development Kit runs on Atari 520, 1040, and Mega-ST computers. The package includes a text editor with which you can write assembly-language programs for a wide variety of 4-, 8-, and 16-bit μPs and microcontrollers. The table-driven

crossassembler translates the source code into the target machine's native code. The crossassembler contains tables for 20 µPs, including the HD64180, Z80, 6502, 68000, 8048, 8051, 8085, 8086/88, and 8096. When you've assembled your program, you can download the object code to the EPROM emulator, which plugs into the target machine's EPROM socket. The emulator is compatible with EPROMs in the 2716 through 27256 families. Access time for the emulator is 150 nsec. For downloading purposes, both the crossassembler and the EPROM emulator can handle Intel Hex, Motorola S-record, and simple binary formats. Most serial EPROM programmers can operate with at least one of these formats. $575.

Memocom, 1920 Arbor Creek Dr, Carrollton, TX 95010. Phone (214) 446-9906.

Circle No 400



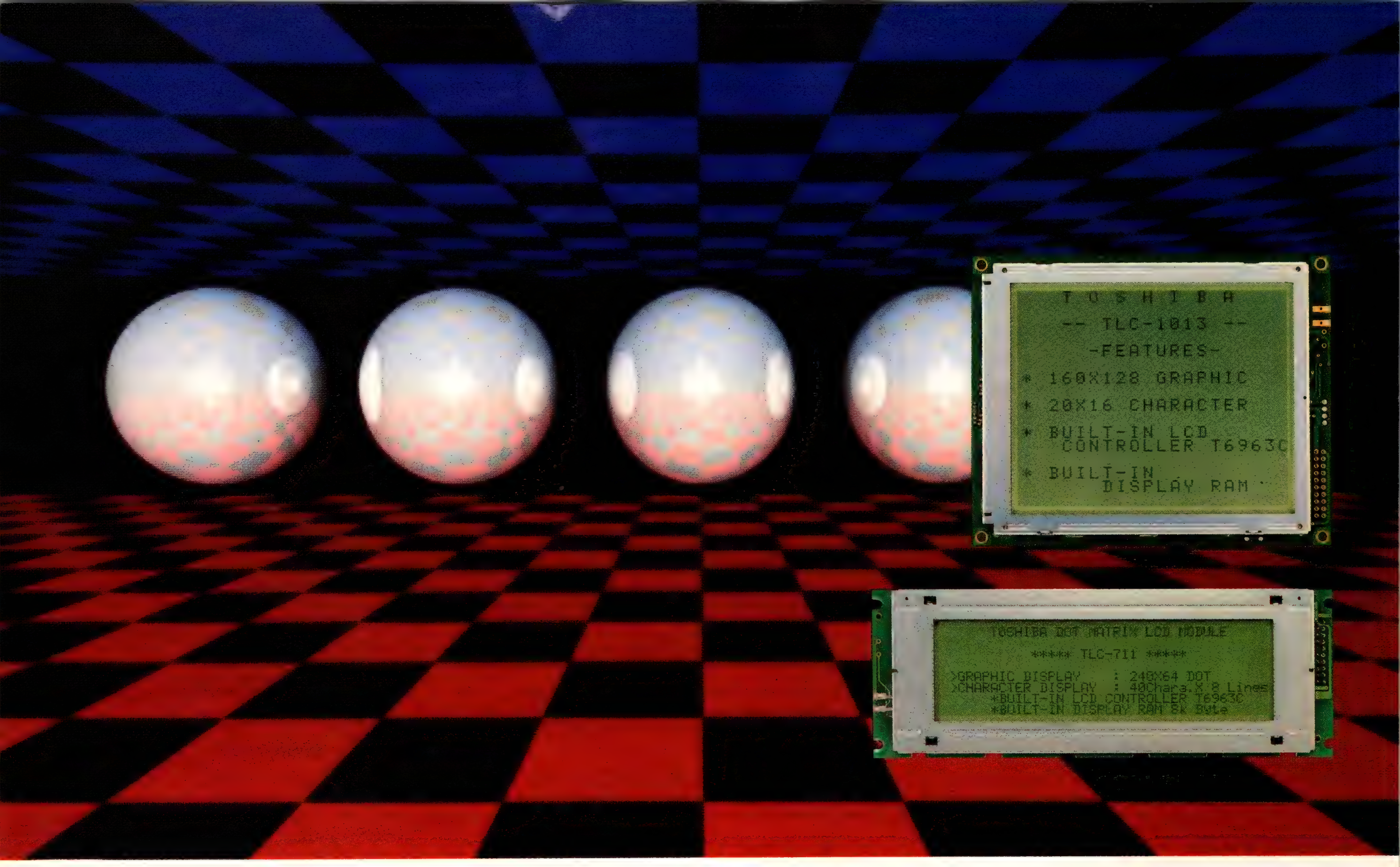
MULTILINGUAL TEXT

- *Word processor can operate in 41 languages*
- *Reconfigures keyboard for different alphabets*

The Intext word processor lets you reconfigure your keyboard for a different language with a single keystroke. In addition to offering the alphabets of European languages such as French, German, and the Scandinavian languages, the program can handle non-Roman alphabets such as Cyrillic and the right-to-left alphabets of Mideastern and Asian languages. You can use templates, caps, and stickers on the keyboard. You can mix languages in a single document and print the output on IBM and Epson printers and compatibles. You can also obtain the program configured for 24-pin dot-matrix printers and laser printers. Jet:Spell, a spelling checker, is available as an option. The program runs on an IBM PC, PC/XT, PC/AT, or a compatible computer that's equipped with at least 384k bytes of RAM and a monochrome display or an IBM CGA or compatible board. The vendor offers the program for more than 41 languages. Intext for two languages, $195; for three languages, $250; Jet:Spell, additional languages, $50 each.

Intex Software Systems International, Ltd, 1 Penn Plaza, Suite 4330, New York, NY 10119. Phone (212) 750-1140. TLX 287960.

Circle No 401



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Character Display Type with Built-in Controller

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Easy-to-use design thanks to high contrast TN.

Model name	Number of characters	Outline dimensions (mm)
TLC-671	16 × 1	80.0 × 36.0 × 12.0
TLC-241	16 × 1	80.0 × 36.0 × 12.0
TLC-491	16 × 2	80.0 × 36.0 × 12.0
TLC-731	16 × 4	87.0 × 60.0 × 12.0
TLC-501	20 × 2	116.0 × 37.0 × 12.5
TLC-721	20 × 4	98.0 × 60.0 × 12.0
TLC-691	24 × 1	126.0 × 36.0 × 12.0
TLC-771	24 × 2	118.0 × 36.0 × 12.0
TLC-601	40 × 1	182.0 × 33.5 × 13.0
TLC-591	40 × 2	182.0 × 33.5 × 13.0
TLC-1001	40 × 4	221.0 × 76.0 × 12.5

Graphic Display Type with Built-in Controller

Clear display thanks to high contrast TN.
Easy-to-use C/G, RAM and ROM built-in types.

Model name	Number of dots	Outline dimensions (mm)	Controller
TLC-1021	120 × 64	85.0 × 70.0 × 20.0	T6963C
TLC-682	160 × 64	125.0 × 50.0 × 18.0	T6963C
TLC-711A	240 × 64	180.0 × 65.0 × 12.0	T6963C
TLC-1013	160 × 128	129.0 × 104.5 × 14.0	T6963C
TLC-1091	240 × 128	241.0 × 125.3 × 12.0	T6963C
TLC-1101	160 × 32	140.0 × 40.0 × 12.0	T6963C

*We provide many options.
*We can meet the need for customized products.

Graphic Display Type

Clear display through employment of high contrast TN.
Capable of displaying large-size letters and special letters.

Model name	Number of dots	Outline dimensions (mm)	Controller
TLC-612	640 × 32	320.0 × 48.0 × 14.0	(T6963C)
TLC-761	640 × 64	320.0 × 47.0 × 14.0	(T6963C)
TLC-341AK	128 × 128	93.2 × 86.6 × 12.0	(T6963C)
TLC-531A	128 × 128	132.2 × 111.0 × 13.0	(T7755)
TLC-972	480 × 128	274.0 × 114.4 × 20.0	(T7755)

( ): Recommended controller ICs.

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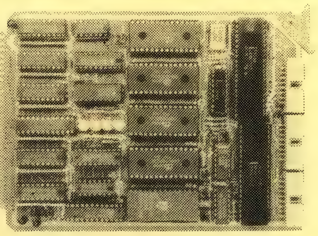

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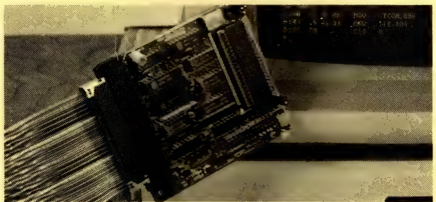
CIRCLE NO 325



8051

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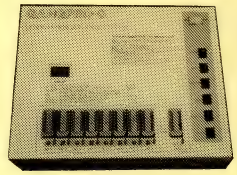

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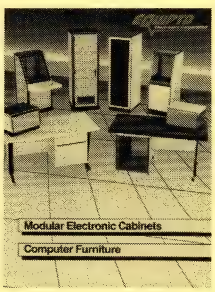

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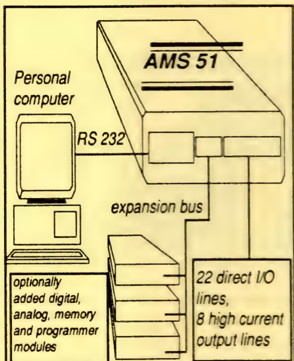

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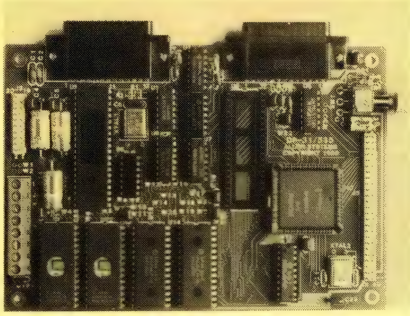

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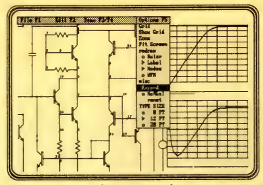

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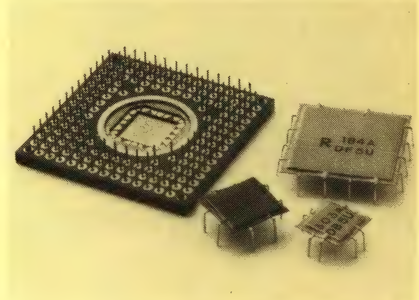

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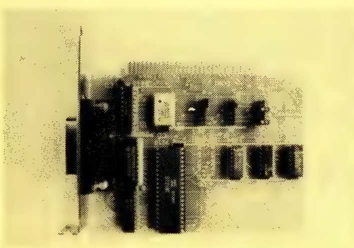

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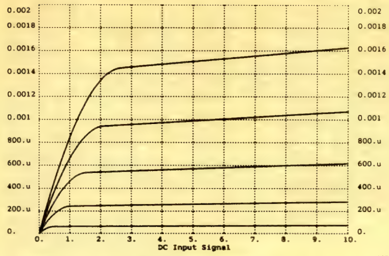

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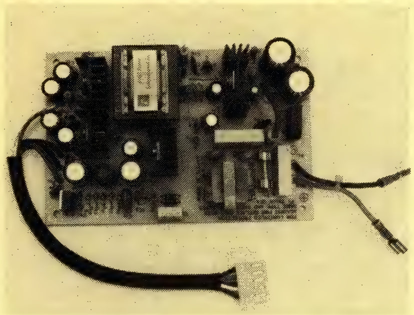

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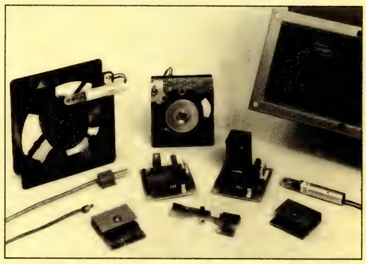

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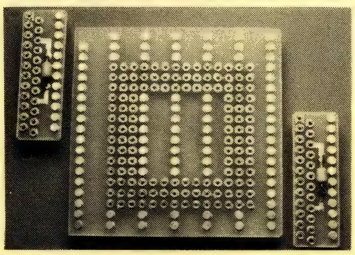

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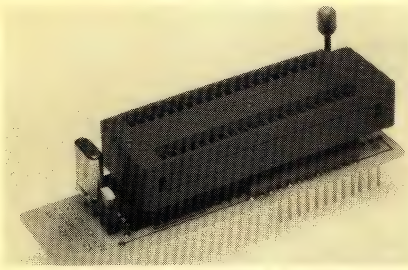

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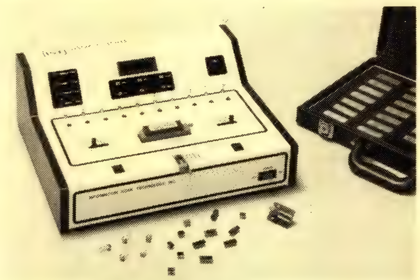

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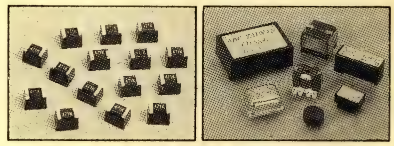

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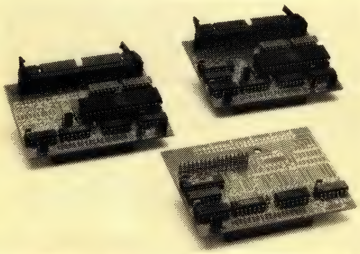

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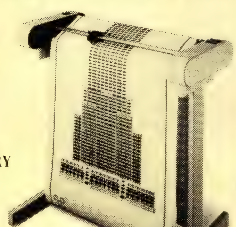

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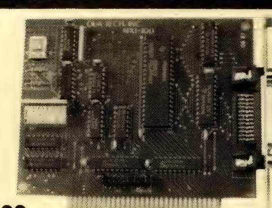

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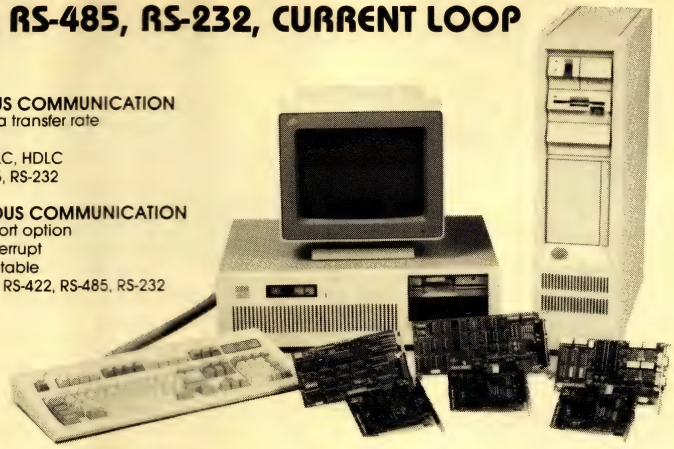

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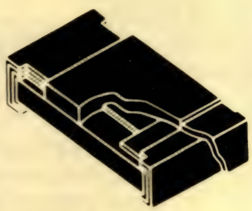

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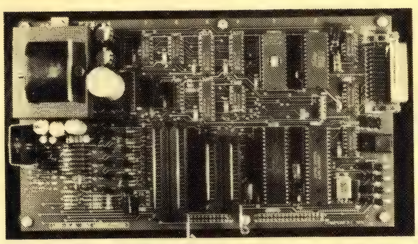

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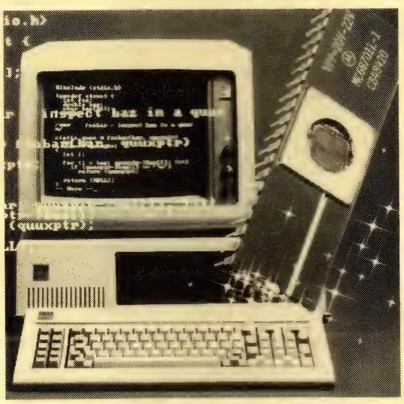

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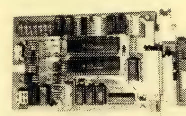

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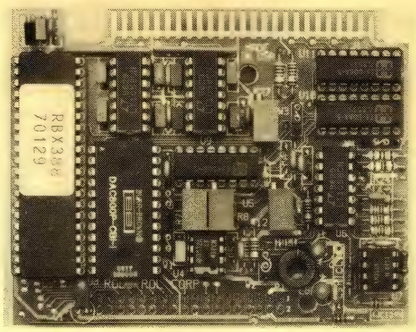

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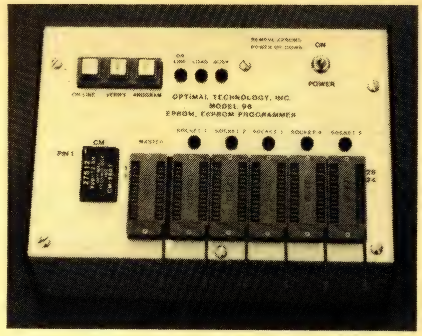

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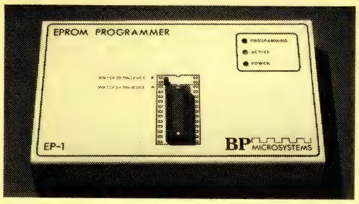

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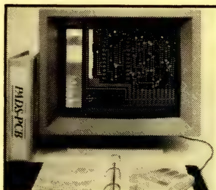

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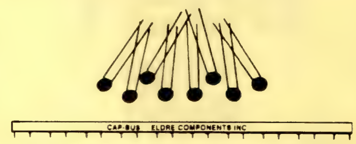

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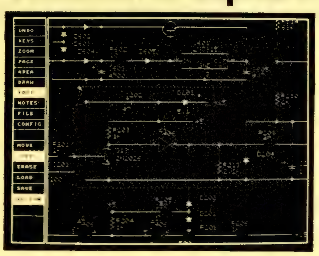

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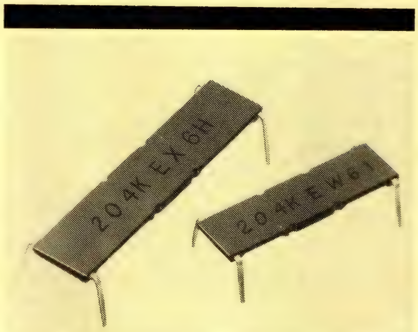

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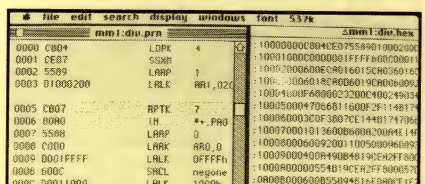

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Cassette course introduces 32-bit μP

The vendor's MC68030 Audio Cassette Course introduces the MC68030 32-bit μP (MTTA3). The course is aimed at engineers and programmers who are already familiar with the earlier MC68000 and MC68020 μP families. The course supplies three tapes, each 3½ hours long, and includes illustrated course notes and related literature. The course covers the major features of the MC68030 including data cache, burst mode, synchronous-bus operations, and the internal memory-management unit. It examines the same information as the instructor-led course, which will be offered in 1988. $125.

Motorola Inc, Technical Information Center, Box 52073, Phoenix, AZ 85072.

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Brochure describes customer-specific memory

The 8-pg pamphlet *Introducing a More Intelligent Approach To Smart Memory* presents information about the vendor's IC design capabilities for customer-specific smart memories. It discusses the approach you should take in order to obtain high-performance memory semiconductors that are suitable for your particular needs.

Vitelic Corp, 3910 N First St, San Jose, CA 95134.

Circle No 382

Pamphlet describes simulator/analyzer

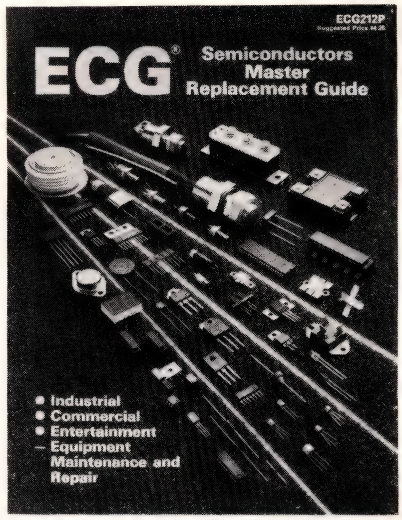
This 6-pg, 4-color document details the features and options of the TE820A DS1/T1 frame simulator/analyzer. It describes applications, including testing and evaluating, troubleshooting, simulation, analyzing, and field testing. A listing of additional options is included.

Tekelec, 26540 Agoura Rd, Calabasas, CA 91302.

Circle No 383

Extensive listing of semiconductors

The Semiconductors Master Replacement Guide categorizes nearly 4000 individual solid-state replacement devices that you can substitute for domestic and foreign types in commercial and industrial equipment. More than 230 types have been added, including 67 transistors and 17 diodes and rectifiers; many of these devices are suitable for surface-mount applications. In addition to transistors and diodes, the product lines include high-voltage rectifi-



ers and triplers; rectifiers from 1 to 2200A; SCRs and Triacs; thyristors; overvoltage transient suppressors; and digital ICs. A table of contents, an alphabetical index, and a numerical product index are included.

Philips ECG Inc, 100 First Ave, Waltham, MA 02254.

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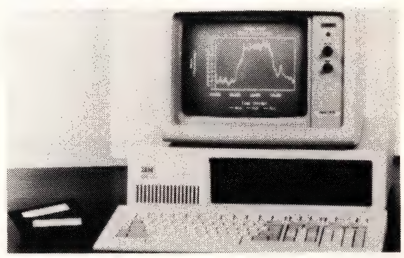

Tutorial disk looks at monitoring system

The IBM PC-compatible disk highlights the applications, features, components, and capabilities of the PowerStar remote-power operating system. This system allows your PC to monitor as many as 96 single and multiphase power loads using the vendor's Series 800 Power/Demand Analyzers. The disk covers applications such as load monitoring, energy management, cost allocation, submetering, and system-load management.

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NEW BOOKS

Electronic Test Equipment, by T J Byers. 335 pgs; $39.95; McGraw Hill Book Co, New York, NY, 1987. Phone (609) 426-5254.

This book covers a range of electronic test equipment from voltmeters to sophisticated analyzers. It is organized by electronic function for easy reference. There are chapters on basic meters, signal generators, signal tracers, counters and frequency monitors, oscilloscopes, bridges, semiconductor testers, and special-purpose test equipment.

Semiconductor Device Modeling with Spice, edited by Paolo Antognetti and Giuseppe Massobrio. 389 pgs; $49.50; McGraw-Hill Book Company, New York, NY, 1987. Phone (609) 426-5254.

This book provides an in-depth discussion of simulation, using Spice. It provides a detailed explanation of the different aspects of using Spice models of both MOS and bipolar transistors. It takes you step-by-step through the modeling process and provides you with information about a variety of semiconductors for designing specific circuit applications. These devices include PN-junction and Schottky diodes, the bipolar junction transistor, the junction field-effect transistor, and the insulated-gate field-effect transistor.

Digital Filter Design, by T W Parks and C S Burrus. 342 pgs; $32.95; John Wiley & Sons Inc, Somerset, NJ, 1987. Phone (201) 469-4400.

This text addresses frequency-domain analysis, design and implementation of linear constant-coefficient digital filters on general-purpose computers, and special-purpose signal processors. It develops design theory, formulas, and algorithms for both finite-impulse-response and infinite-impulse-response filters. It discusses new topics in the area of transition bands, complex approximations, and elliptic function filters.

Electronic Instruments & Measurement Techniques, by F F Mazda. 312 pgs; $69.50; Cambridge University Press, New York, NY, 1987. (800) 872-7423.

This book describes electronic instruments used for making measurements. The first section gives an account of topics which are fundamental to instruments and measurement: units, standards, measurement errors, transducers, and instrument buses. Part two describes the construction and operation of the more common instruments such as ammeters, voltmeters, counters, oscilloscopes, and recorders and amplifiers. The

NEW BOOKS

final section covers the application of many of the general-purpose instruments described previously, but also introduces instruments designed for specialized applications.

The Arthur Young Practical Guide to Information Engineering, by Arthur Young Information Technology Group. 182 pgs; $32.95; John Wiley & Sons Inc, Somerset, NJ, 1987. Phone (201) 469-4400.

This text is a guide to building information systems that further business goals and assist management in its decision-making role. The guidelines allow data-processing managers, project managers, systems analysts, and designers to customize an information engineering model on a project-by-project basis.

Electrical and Electronics Graphic Symbols and Reference Designations. The Institute of Electrical and Electronics Engineers Inc. $29.95. New York, NY, 1987. Phone (201) 469-4400.

This standard defines an international language to determine the functional behavior of a logic circuit as described on a logic or circuit diagram with minimal reference to supporting documentation. The book is divided into six sections: Part 1 includes all of the standard housekeeping information and definitions of terms. Part 2 defines the basic parts of a symbol and discusses the connections within the symbol that are implied when outlines are combined in various ways. Part 3 defines all of the basic symbols and labels that are associated with individual inputs and outputs. Part 4 defines more complex input/output labels and notational techniques. Part 5 defines symbols for the overall function of an element and presents examples of symbols for numerous real-world devices, and part 6 defines techniques for concise representation of complex logic functions.

In late 1986, Professional Issues profiled the engineering staffs of two start-up companies—one backed by venture capital, the other bootstrapped by its founders. Here is a look at how each company fared during the past year.

A TALE OF TWO START-UPS
ONE YEAR LATER

For Edge Computer's engineers, it's back to the drawing board

This time, the engineers at Edge Computer Corp aren't taking any chances. The 14 men designing the company's next-generation product line have left their private offices and now sit in communal, 3- or 4-person cubicles in one area of their employers' Scottsdale, AZ, headquarters.

The engineers' first product, the Edge1 engineering-graphics workstation made its debut in March 1986 and met with less than dazzling success. The Edge1's price/performance advantage initially garnered some interest, but the workstation quickly lost ground to products offered by industry heavyweights Sun Microsystems and Apollo Computer. As sales of the workstation sagged—more because of marketing mistakes, observers say, than any technical deficiencies—Edge Computer decided to regroup. A year later, the Edge1 was back on the market, repackaged as a high-end superminicomputer and targeted at OEMs and value-added resellers.

Edge Computer's business fortunes have fluctuated since the company's 1983 founding. But for the 28 members of its engineering staff, some things remain unchanged. For example, the engineers still work long hours on designs that they hope will lead Edge Computer to profitability. Many of the engineers have been with the company since its start, and four years of working 55-hour-plus weeks have sharpened not only their design skills, but also their ability to balance heavy workloads with home and family responsibilities.

Ron Bernal, a founder of Edge, is now its director of advanced product development. He led the design of Edge Computer's first product and now leads the team working on the soon-to-be-introduced Edge 2000, a superminicomputer that implements the 680X0 instruction set. Bernal says that there's "no comparison" between the vast technical experience he has gained because of his involvement with a start-up and the knowledge he would have gained while working for an established company. While working on the Edge 2000, for example, he has supervised the design of the operating system, compilers, and firmware.

But the experience comes at heavy cost. He typically works 75 hours a week and says a 60-hour week "would feel like a vacation." And, although Bernal speaks enthusiastically of his work, he concedes that his mounting responsibilities have been accompanied by mounting frustrations. "There's a hole in my office wall where I bang my head against it," he says. "The frustrations come from dealing with people and in

Deborah Asbrand
Associate Editor

trying to get my ideas across. Electronics and physics are deterministic; people are not."

Other engineers say that the challenge of balancing their professional and personal lives has been as demanding as the technical work. Logic designer Dan McCarthy, now working on some of the cache memories for the new product's processor, says he's still adjusting to the new demands on his time that arose with his daughter's birth one year ago.

A 60-hour week "would feel like a vacation," says Bernal.

Project manager Roger Luce is one of the 10 engineers who left the computer division of copier maker AB Dick in 1983 to form Edge Computer. He designed the memory and I/O subsystem for the company's first project. Vivid recollection of his arduous contributions to that project, he says, "made it a little harder to get up the enthusiasm this time." One way that he helped create and sustain his enthusiasm for the latest project was by asking for a new design assignment; for the past year, he has been designing a new CPU.

His prior experience in balancing home and work responsibilities is another advantage. The long hours Luce spent designing the company's first product line left little time for his wife and two children and put a strain on his family. Now, he says, he knows the symptoms that indicate he needs to spend more time at home. "The hardest part is recognizing what's happening. When tensions arise at home, you have to realize that it's because you've been away too much or you're too tired," he says. "It's to your advantage to be able to do so because then you can correct the problem."

Indeed, Bernal's awareness of the stresses and general fatigue that are likely to plague his engineers after such a protracted period of hard work led him to look for ways to instill new vigor in the group. Bernal originally wished to set up a "skunk works," an off-site location where the engineers could complete their designs free of the everyday interruptions that pervade most office settings. Instead, however, he settled on locating the engineers in a more isolated area within the company's main facility. "We wanted to enhance creativity and allow spontaneous communication to occur," he says of his decision to create what some of his engineers jokingly refer to as "the dungeon."

Perhaps even more important than the intimate work setting, though, is the engineers' experience in working with one another. Most of the engineers working on the next-generation product have been with Edge from the start. As a result, they're familiar with each others' work styles and habits. Luce believes this human aspect of the team will translate to a better product. Working long hours together, says Luce, means "that you get to know the people, and people are definitely the most important part of a company." **EDN**

Owl Computer never took off, but its founder says he'd do it again

In his new job, Gene Bartsch occasionally finds himself reverting to old habits. When important company decisions have to be made, he finds himself wanting to make them—as if he were running the company. And although he says his new employer gives him plenty of freedom to do his job, managing the development of a new product line, it's not the same as being the company president, which is what Bartsch was for three years.

> "You can read all of the books you want," Bartsch says, ". . . but if you don't [try building a company] of your own, you never really know what it's like."

From 1984 to 1987, Bartsch poured all his energy into the Owl Computer Company, a manufacturer of 32-bit VME Bus and Multibus board sets that he operated out of his Encinitas, CA, home. He and nine other engineers had pooled $70,000 of their savings and founded the business in 1984. With Bartsch working for the business full time and the other members of the team moonlighting for it, Owl Computer produced a Multibus board set, a VME Bus processor board, a software cross-development system, and a ROM simulator. Bartsch estimates that 15,000 hours of unpaid labor went into the products.

In early 1987, however, Bartsch and the other founders studied the company's vital signs and didn't like what they saw. Intel's 80386 chip was taking off in the marketplace, eclipsing National Semiconductor's 32000 Series, on which Owl had based its products. Sales of Owl's products were dropping, and the company needed cash. Keeping the company alive, the group decided, meant designing a 386-based product line.

At a meeting last March in Bartsch's living room, Owl's founders discussed their next step. One by one, each voiced his or her feelings regarding the company's future. The decision to close shop was unanimous. "For the most part, we were tired," Bartsch recalls. "We had spent a lot of time on the first product line, and we decided we didn't want to do another." Two members of the group were interested in running the company part time, and Bartsch handed them the management reins. In April, Bartsch accepted a full-time position with a large company, and he and his family moved to the Sacramento area.

Owl's demise both saddened and relieved Bartsch. During his three-year involvement with it, the company occupied not only his days, but also his nights and weekends. He estimates that those three years equaled "about 25 years of experience" and resulted in more than a few gray hairs. The knowledge that he acquired, though, is an invaluable asset. "Even though the outcome wasn't what I'd hoped for, it wasn't a complete loss by any means. It's going to help me in anything I do in the future, whether it's working for a large company or another start-up."

Bartsch believes two mistakes, in particular, hampered the company's chances for success. The first was its too-ambitious product line. In addition to the board-level devices that the company designed, Owl acquired a line of software products that included a cross-assembler, a utility package, compilers, and a real-time operating system. "With our limited resources, it was a large burden," Bartsch says. The company also erred through its dependence on third-party subcontractors. "We relinquished control of too many things," he remembers.

When he left Owl, Bartsch was ready for the comforts of a more established corporation. Before accepting his present job, he interviewed with five companies, two of which were start-ups. "I remember one guy telling me that things at his company were uncertain," Bartsch says. "I had just been through that. I wanted more security."

Bartsch feels rested and relaxed in his new environment. He and his family live in the quiet suburb of Shingle Springs, CA. Bartsch says that he quickly adjusted to his 15-mile daily commute to the office. Managing new-product development attracted him because there are "many entrepreneurial aspects to it," he says. "I have a surprising amount of freedom."

He looks back on his experiences at Owl with no small measure of satisfaction. "You can read all of the books you want and study all of the reports, but if you don't [try building a company] of your own, you never really know what it's like." **EDN**

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Jan. 21	Dec. 30	Microprocessors, Software, Components	
Feb. 4	Jan. 14	Semicustom ICs, Computors & Peripherals	Closing: Jan. 21 Mailing: Feb. 11
Feb. 18	Jan. 28	Materials & Hardware, CAE, Power Sources	
Mar. 3	Feb. 11	Communications, CAE, High-Speed Logic	Closing: Mar. 3 Mailing: Mar. 24
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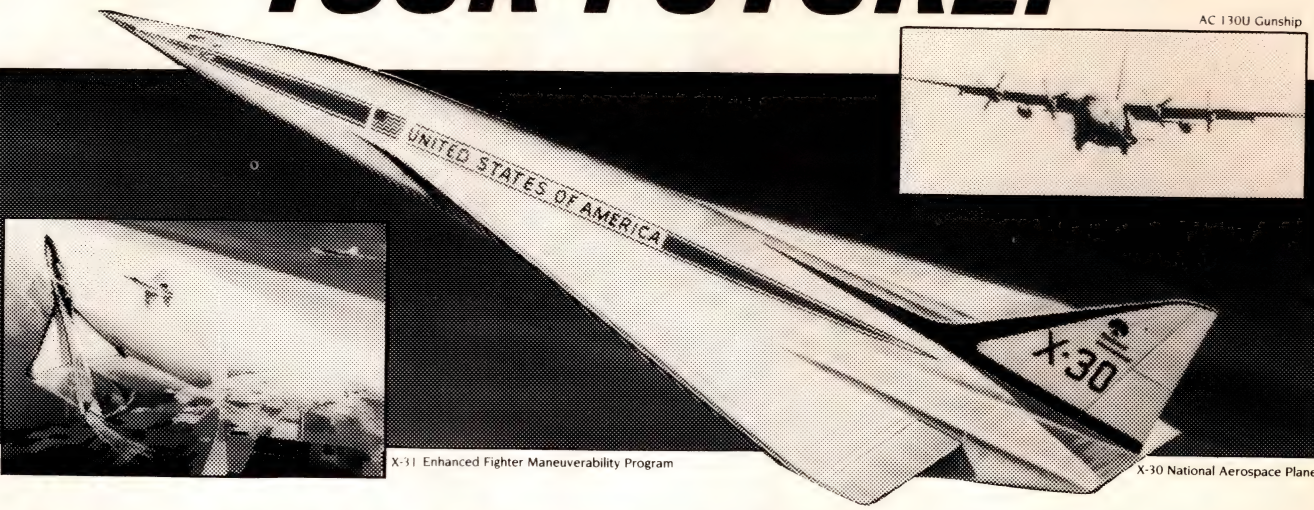

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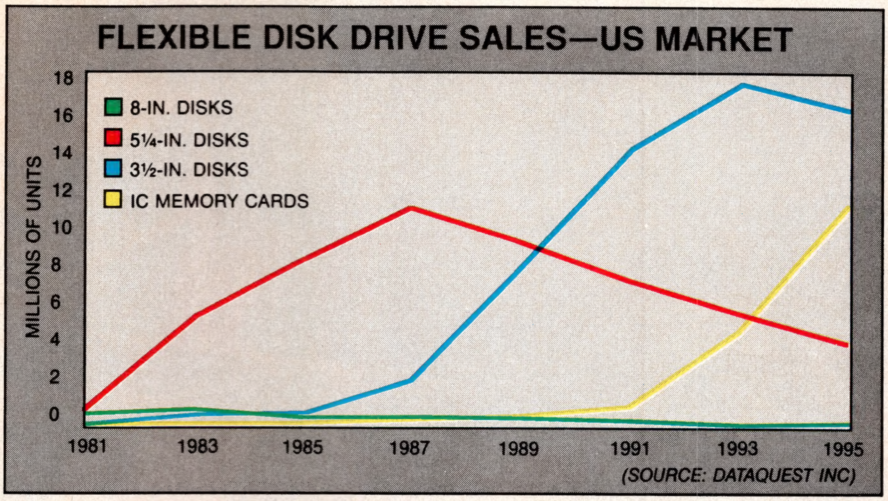
LOOKING AHEAD

EDITED BY CYNTHIA B RETTIG

IC memory cards should constitute a winning hand



Something is bound to replace the floppy disk, and Dataquest Inc has gathered substantial evidence suggesting that the IC memory card is the pre-eminent candidate. Such memory cards—which promise high-capacity, solid-state storage—are soon to become commercially viable alternatives to the 8-, 5¼-, and 3½-in. floppy disks that now dominate the removable-memory storage-device market.

According to research and analysis conducted by the San Jose, CA, firm, manufacturers are successfully tackling the prohibitively high cost of these memory modules, and the resulting lower prices will increase the stature of the devices in the market within the next few years. Having evaluated the history of the floppy-disk industry and the life cycles of its products in conjunction with recent technological advances and an expected drop in chip prices, Dataquest projects a steady growth in demand for IC memory cards. Indeed, the company expects 12 million units to be sold in the US market in 1995. This projection is partly supported by the large sample orders that major computer vendors have already placed for currently available products.

Three technological developments are promoting the commercial progress of IC memory cards: higher capacities, as represented by the 1M-byte RAM chips already on the market; surface-mount techniques; and tape-automated bonding of ICs. The last two have opened the door to the construction of units as compact as they are rugged. It's now possible, for example, to put a 512k-byte static RAM and battery in a package the size of a credit card.

Dataquest points out that installation damage to IC memory cards is far less likely than it is to hard-shelled 3½-in. floppy disks. In the first place, the chips are mounted on flexible tape; secondly, manufacturers can recess a female connector on the card and place fragile contact pins within the computer. Consequently, there are no pins to bend when the cards are moved from place to place.

Although IC card manufacturers initially aimed their cards at CPU memory-expansion applications, they now employ them as floppy- and rigid-disk replacements. Thus, software can address files logically, and, like rotating mass storage, avoid defective areas.

The greatest demand will probably be for IC memory cards with battery-backed RAM. The batteries' standard minimum life specification is 2.5 years, and a card's batteries are replaceable while the card is residing within the host, because the card is then utilizing the host's supply. For software distribution, however, vendors will most likely use ROM memory and eliminate the need for backup power altogether.

The cards will be used in various applications. Once prices have declined substantially, vendors will use the cards for distributing their software. The cards can also facilitate the safe exchange of data files both within an office and outside it. Furthermore, the units provide a simple means for temporary work storage; their rugged qualities make them suitable for factories and other harsh environments. Secure disk backup is another very likely application. Finally, IC memory cards that transfer personality modules among printers are already available. The first substantial use of these removable modules should occur in the MS-DOS PC market.

Prices for IC memory cards should follow the general industry rule and decline dramatically within the next few years. Currently, a 256k-byte card costs about $50—or $200 per megabyte of storage capacity. By comparison, high-capacity hard disks run close to $5 per megabyte, whereas a 360k-byte 5¼-in. floppy disk boasts a retail price of less than $1. Dataquest conservatively estimates that manufacturers will be able to produce a 2M-byte IC card for $10 per megabyte by 1989, and that by 1992 increasing production volumes will decrease that cost to roughly $5 per megabyte of storage.

IC memory cards will grow in popularity as the product-life cycle of floppy disks begins its decline. Floppy-disk makers have five more years of robust sales in which to plan their reaction to the prominent market share that the now infant IC memory card should command by 1995.

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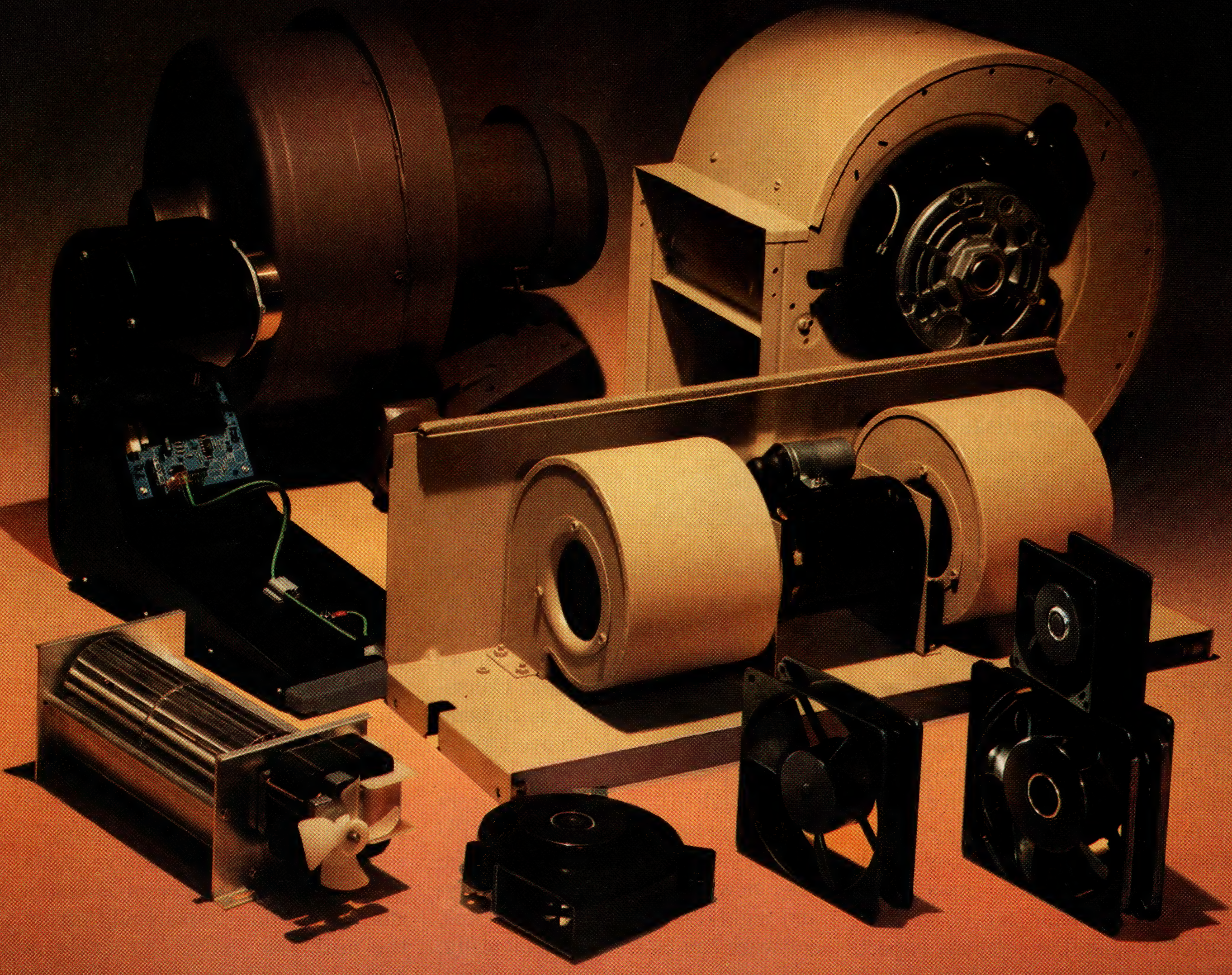

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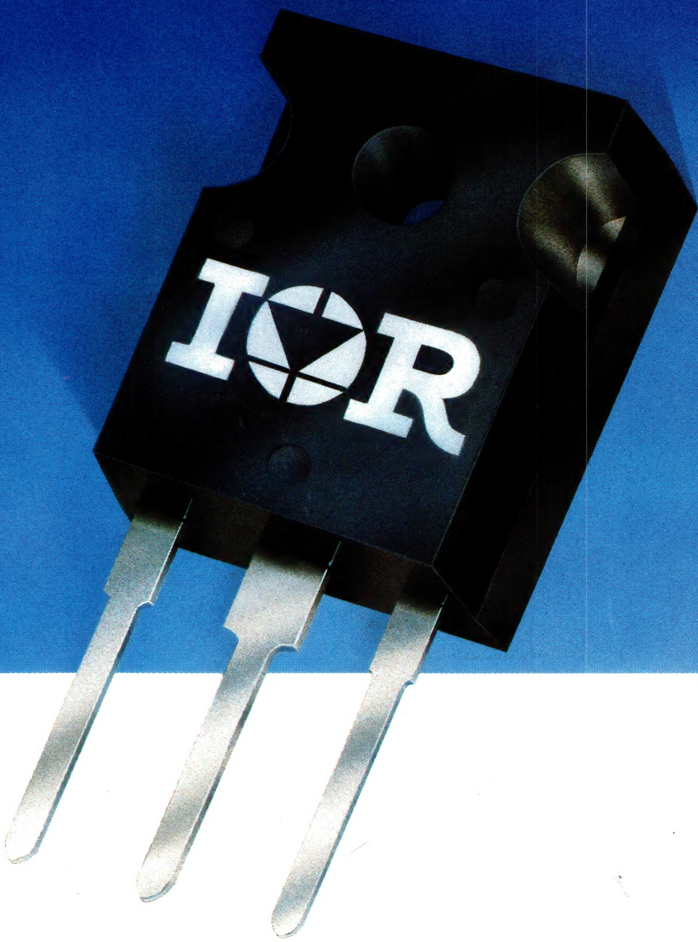

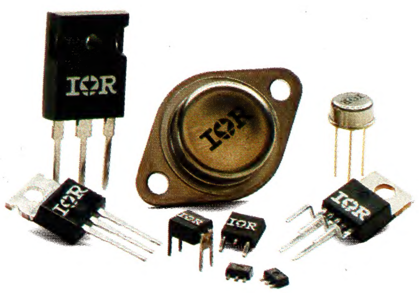

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